US Army Corps of Engineers
Waterways Experiment Station

Instruction Report ITL-96-3
September 1996

Computer-Aided Structural Engineering (CASE) Project

User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Design Criteria (CMITERW-LRFD) Windows Version

by Guillermo A. Riveros

Approved For Public Release; Distribution Is Unlimited

Prepared for Headquarters, U.S. Army Corps of Engineers

Computer-Aided Structural Engineering (CASE) Project

Instruction Report ITL-96-3
September 1996

User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Design Criteria (CMITERW-LRFD) Windows Version

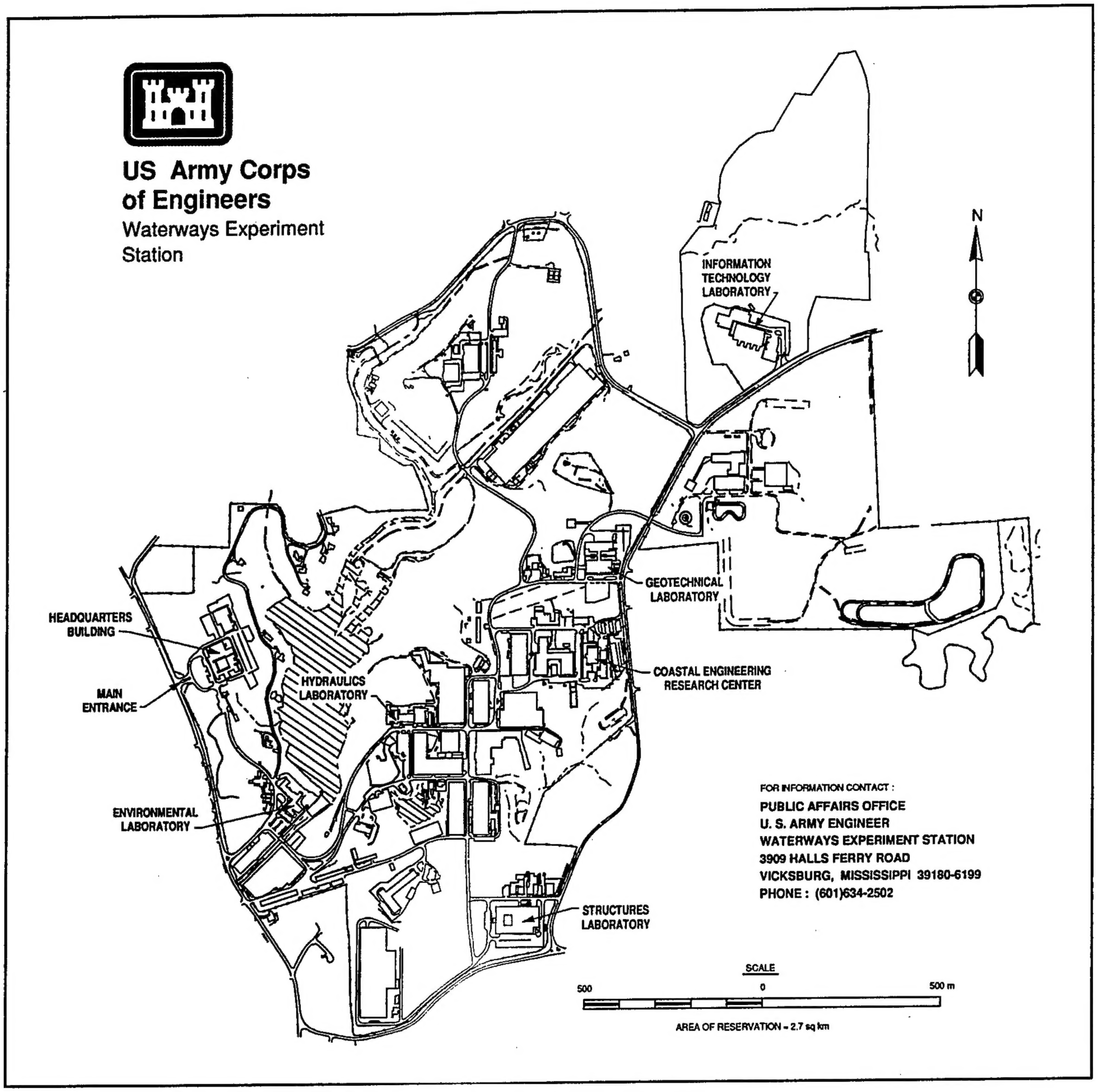
by Guillermo A. Riveros

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



Waterways Experiment Station Cataloging-in-Publication Data

Riveros, Guillermo A.

User's guide : computer program for the design and investigation of horizontally framed miter gates using the load and resistance factor design criteria (CMITERW-LRFD) Windows version / by Guillermo A. Riveros ; prepared for U.S. Army Corps of Engineers.

194 p. : ill. ; 28 cm. -- (Instruction report ; ITL-96-3)

Includes bibliographic references.

1. Hydraulic gates -- Computer programs -- Handbooks, manuals, etc. 2. CMITERW-LRFD (Computer program) 3. Hydraulic structures. 4. Load factor design. I. United States. Army. Corps of Engineers. II. U.S. Army Engineer Waterways Experiment Station. III. Information Technology Laboratory (U.S. Army Engineer Waterways Experiment Station) IV. Computer-aided Structural Engineering Project. V. Title. VI. Title: Computer program for the design and investigation of horizontally framed miter gates using the load and resistance factor design criteria (CMITERW-LRFD) Windows version. VII. Series: Instruction report (U.S. Army Engineer Waterways Experiment Station) ; ITL-96-3.

TA7 W34i no.ITL-96-3

Contents

List of Figures

List of Tables

Preface

This report presents the user's manual for CMITERW-LRFD computer program to design and investigate horizontally framed miter gates using load and resistance factor design (LRFD) criteria. Funding for the development of the program and preparation of this report was provided to the Scientific and Engineering Applications Center (S&EAC), Computer-Aided Engineering Division (CAED), Information Technology Laboratory (ITL), U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, MS, by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the computer program and the LRFD criteria for miter gates were prepared by members of the CASE Steel Structures Task Group Committee. Members of the task group during the development of the program included the following:

Eugene A. Ardine, Retired
Cameron Chasten, Philadelphia District
Ray Dewey, Portland District
Joe Hartman, HQUSACE
Nathan Kathir, St. Paul District
Tom Ruf, St. Louis District
Henry Stewart, North Central Division
William Wigner, Jacksonville District
Joe Padula, WES
H. Wayne Jones, WES
Guillermo A. Riveros, WES

The original CMITER computer program, Instruction Report ITL-88-2, was enhanced to include LRFD by Mr. Guillermo A. Riveros, WES. The graphic interface was prepared by Mr. Riveros and Mr. Mark Elliot (DynCorp), and the final report was written by Mr. Riveros under the supervision of Mr. Barry Fehl, Chief, S&EAC, Mr. H. Wayne Jones, Chief, CAED, and Dr. N. Radhakrishnan, Director, ITL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
feet	0.3048	meters
inches	0.0254	meters
kips	4.448	kilonewtons
kips per square foot	47.88026	kilopascals
kips per square inch	6894.757	kilopascals
pounds (force) per square inch	0.006894757	megapascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290	square meters
tons (2,000 pounds)	907.185	kilograms

1 Introduction

Background

Lock gates serve several different functions, depending on locations and conditions. The major use of lock gates is to form a damming surface across a lock chamber, but the gates may also be used to serve as guard gates, to fill and empty a lock chamber, to allow ice and debris to pass, and to provide access from one lock wall to the other by means of walkways or bridgeways installed on top of the gates. A navigation lock requires closure gates at both ends of the lock so the water level in the lock chamber can be varied to coincide with that in the upper and lower approach channels. Many locks in the United States are equipped with double-leaf miter gates that are used for moderate- and high-lift locks, having a height of 20 to 80 ft[1] and a chamber width of 56 to 110 ft. These gates are fairly simple in construction and operation and can be opened or closed more rapidly than any other type of gate. Maintenance costs are generally low.

Miter gates are framed either horizontally or vertically. The skin plate of a horizontally framed gate is supported by horizontal members that may be either circular arches or straight girders acting as beams (Figure 1). Each horizontal member is supported by a vertical quoin post at one end and a miter post at the other (Figures 1-3).

A vertically framed gate resists water pressure by use of a skin plate supported on a series of vertical girders almost uniformly spaced along the length of the gate. The vertical girders are supported at the top and bottom by horizontal girders that transmit the loads to miter and quoin at the top of the leaf and directly to the sill at the bottom (Figure 4). Due to the greater rigidity and resistance to boat impact of the horizontally framed miter gates and the insignificant difference in cost, vertically framed gates are no longer designed by the U.S. Army Corps of Engineers (USACE) except in unusual applications and with special approval from Headquarters, USACE.

[1] A table of factors for converting non-SI to SI units of measurement is presented on page xiv.

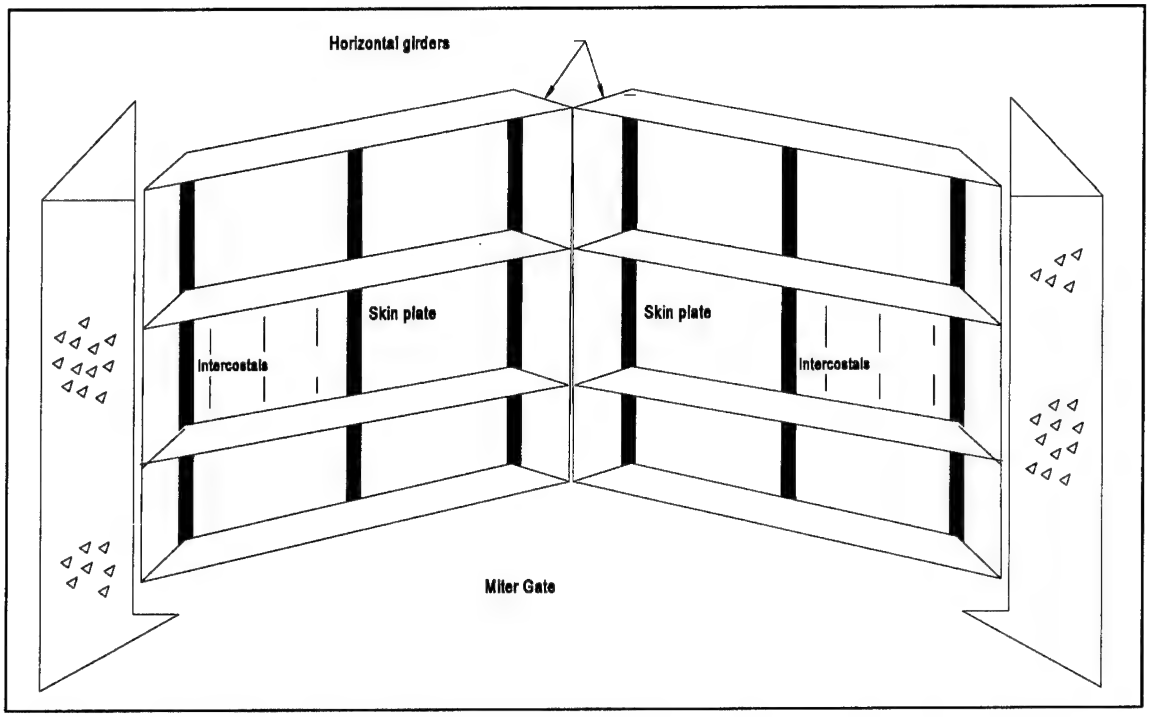


Figure 1. Downstream view of basic structural elements of horizontally framed miter gate

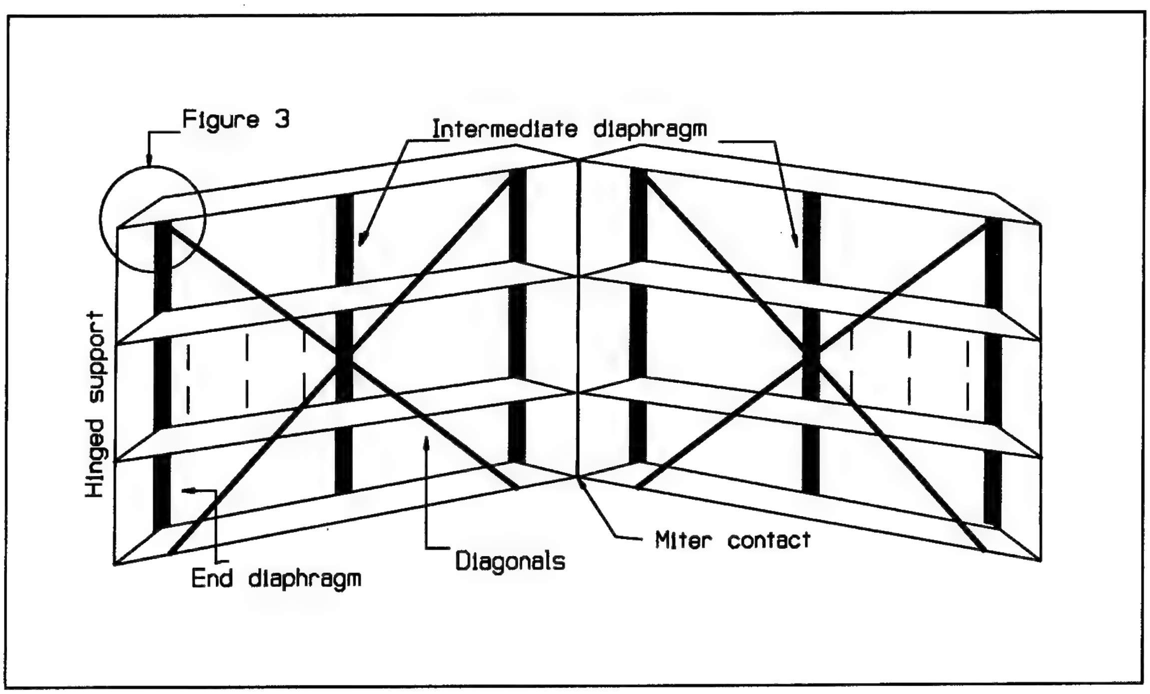


Figure 2. Downstream view of detailed structural elements of horizontally framed miter gate

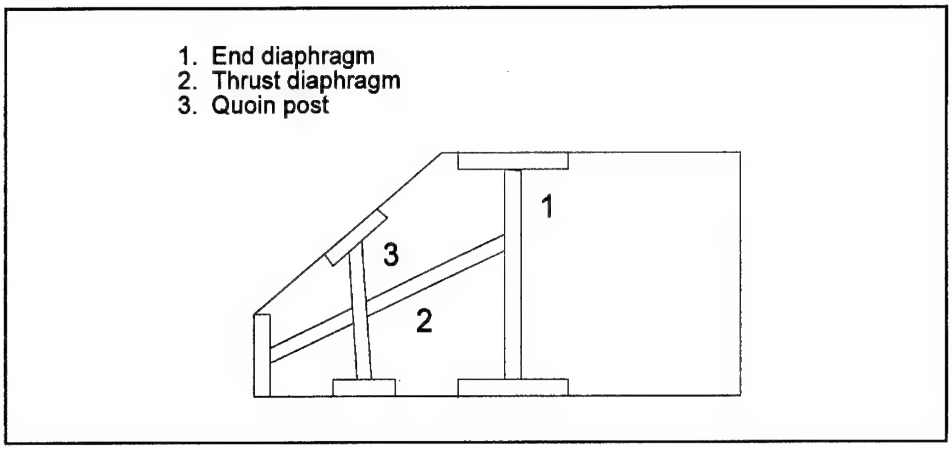


Figure 3. Top view of tapered end section of horizontally framed miter gate

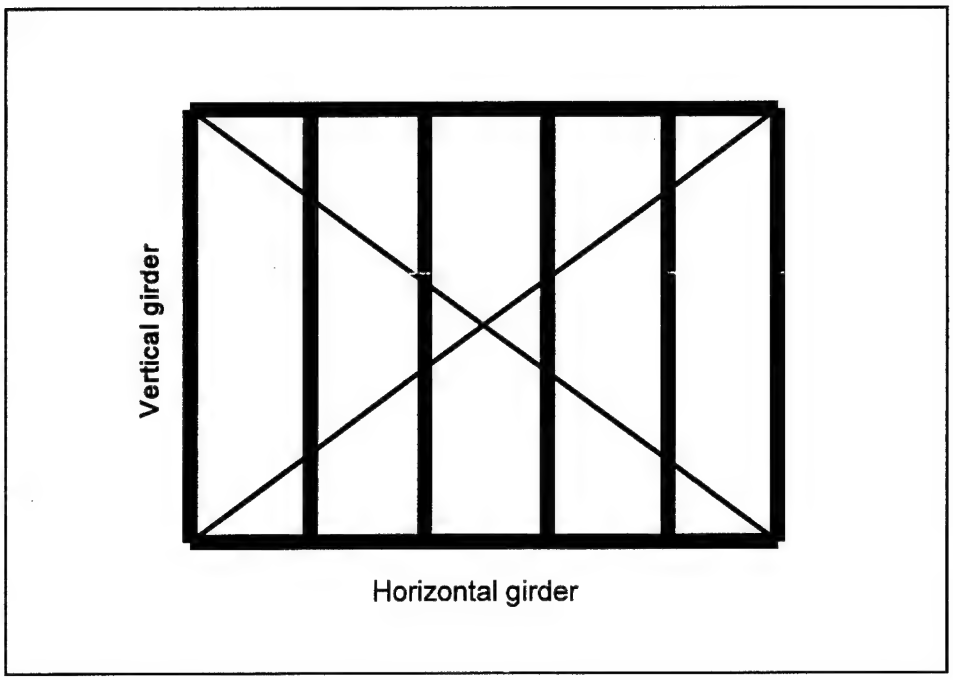


Figure 4. Downstream view of vertically framed miter gate

USACE has developed the computer program CMITERW for the analysis and design of horizontally framed miter gates with the skin plate on the upstream face only. This program comprises three principal modules:

a. A recommended design module, which suggests girder web depth, girder spacing, and the spacing and sizes of the intercostals.

b. A design module, which is used to design the basic and detailed gate leaf elements (Figures 1 and 2).

c. An investigation module, which is used to investigate the integrity of elements in an existing gate.

Design Criteria

The computer program CMITER (Headquarters, Department of the Army 1988) is based on allowable stress design (ASD) criteria specified in Engineer Manual (EM) 1110-2-2703 (Headquarters, Department of the Army 1984) and in the American Institute of Steel Construction (AISC) (1989) manual. In the past, basic guidelines for design of hydraulic steel structures (HSS) have been in accordance with the ASD criteria in EM 1110-2-2703 and the AISC (1989) manual. The ASD criteria have usually yielded safe and reliable structures. However, the criteria do not recognize differing variability in loads and resistances. Therefore, to obtain structures with a more uniform reliability, a load and resistance factor design (LRFD) approach (EM 1110-2-2105 (Headquarters, Department of the Army 1992)) has been adopted by most specification writing committees. Criteria in the LRFD approach have two main advantages over the ASD criteria. First, a limit state analysis does not have to follow linearity between load and force, or between force and stress. Second, the application of multiple load factors can be used to reflect the degree of uncertainty for different loads. Also, application of multiple resistance factors reflects differing uncertainties in a particular resistance (bending capacity, shear capacity, etc.). Due to these advantages, more uniform reliability is achieved in the design process.

Objectives

General objectives of the work discussed herein are as follows:

a. Update the CMITER program for the analysis and design of horizontally framed miter gates to include the LRFD specifications established by USACE.

b. Create a graphic preprocessor that allows the user to generate the input files required to run the program by the presence of graphics and sketches.

c. Create a graphic postprocessor that allows the user to see the program results graphically.

d. Describe the criteria used in the CMITERW-LRFD program to design and investigate the elements in a horizontally framed miter gate.

e. Present the program's user manual.

f. Present an example that will help the user generate the input files required by the program.

2 LRFD Criteria for Miter Gates

Scope

This chapter presents the criteria used in the CMITERW-LRFD program to design and investigate the main structural elements of horizontally framed miter gates. The gates are shown schematically in Figures 1 and 2. The criteria include specifications of applied loads, load cases, load combinations, and analysis methods used in the program. Design methods described herein are in accordance with those given in EM 1110-2-2105 and AISC-LRFD (1986).

Design Basis

LRFD is a method of proportioning structures in such a manner that no applicable limit state is exceeded when the structure is subjected to all appropriate design load combinations. The basic safety check in LRFD may be expressed mathematically as

$$\Sigma\gamma_i Q_{ni} \leq \alpha\phi R_n$$

where γ_i denotes the load factors that account for variability in the loads to which they are assigned, and Q_{ni} represents nominal (code-specified) load effects. The expression $\Sigma\gamma_i Q_{ni}$ is the required strength. Load factors and load combinations for miter gate design are listed later in this chapter. R_n is the nominal resistance, and ϕ is a resistance factor that reflects the uncertainty in the resistance for the particular limit state and, in a relative sense, the consequence of attaining the limit state. The factor α is a reliability factor of 0.9 for HSS except for the structures described below, for which α is 0.85:

a. HSS for which inspection and maintenance are difficult because the HSS is normally submerged, and removal of the HSS causes disruption of a larger project. Examples of this type of HSS include tainter valves and leaves of vertical lift gates which are normally submerged.

b. HSS in brackish water or seawater.

The product $\alpha\phi R_n$ is termed "the design strength for HSS."

Gate Properties

General geometry

The general framing of a horizontally framed miter gates is divided into two groups: basic structural elements that include the skin plate, intercostals, and plate girders that comprise the majority of the weight in the gate (Figure 1); and detailed structural elements that include the tapered-end section, end diaphragms, quoin post, thrust diaphragm, and diagonals (Figures 2 and 3).

Structural steel

Lock gates are usually constructed of structural-grade carbon steel having a yield point of 36,000 psi. Low-alloy steel with a yield point up to 50,000 psi may also be used and is frequently used for the skin plate with girders of 36,000-psi steel.

Loads and Reactions

The principal types of loads applicable to miter gate design are gravity, hydraulic, operating, barge impact, and earthquake loads. Reactions and load cases are generally considered in two categories: gate in the open or intermediate position with no pool differential, and leaves mitered and supporting the full hydrostatic load.

Vertical loads

Vertical loads consist of the dead load of the gate, mud, and/or ice.

Hydraulic loads

Hydraulic loads consist of static water load on the gate produced by the pool differential and temporal hydraulic loads (Figure 5).

The effect of temporal loads on the gate due to waves, surges, etc., can be evaluated with appropriate conditions selected. A minimum temporal hydraulic load of 1.25 ft acting from the full submergence elevation (ELFS) down to the sill, with a period exceeding 30 sec (thus considered static), is specified in EM 1110-2-2703.

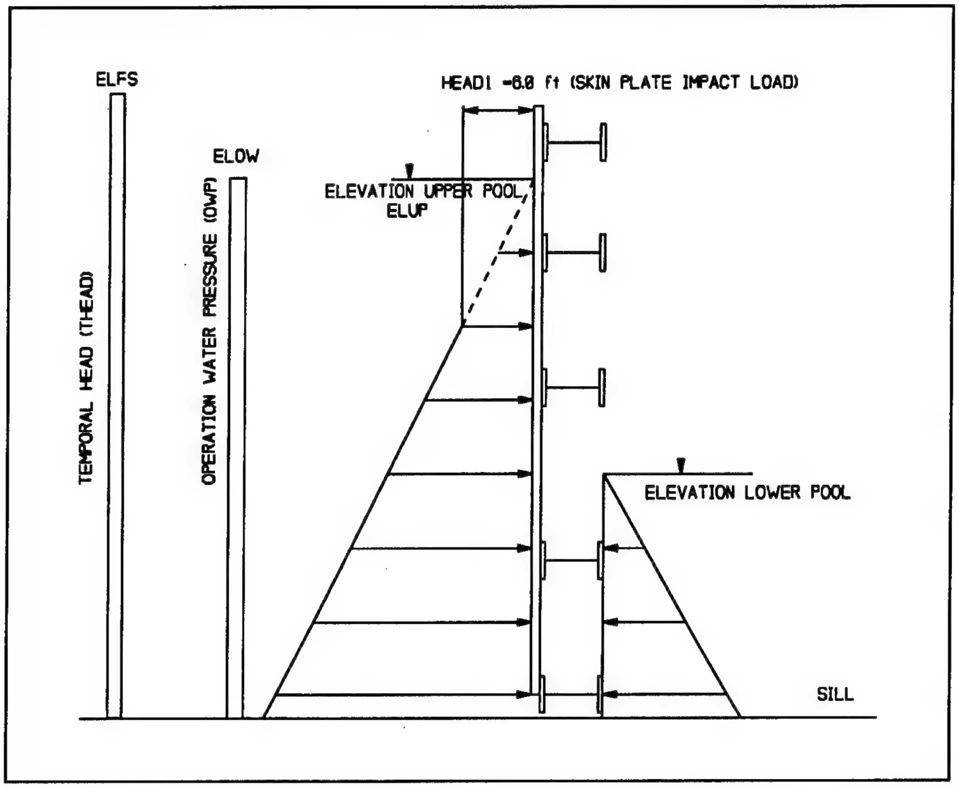


Figure 5. Hydrostatic loads acting on a horizontally framed miter gate

Operating loads

Operating load is the maximum load exerted by the operating machinery (obtained from the mechanical engineer who designed the machinery) and is considered for cases in which the gate is held by a submerged obstruction.

Barge impact loads

A barge impact load is a dynamic load applied to the gate when struck by a barge. The barge impact load is specified as a point load, and it is applied to the girders above the pool level in the downstream direction at the miter point (symmetrical impact) and anywhere in the girder span at which a single barge may impact (unsymmetrical impact) (Figure 6). This location is anywhere in the span at least 35 ft (standard barge width) from either lock wall. The impact load (I) is 250 kips for unsymmetrical loading and 400 kips for symmetrical loading.

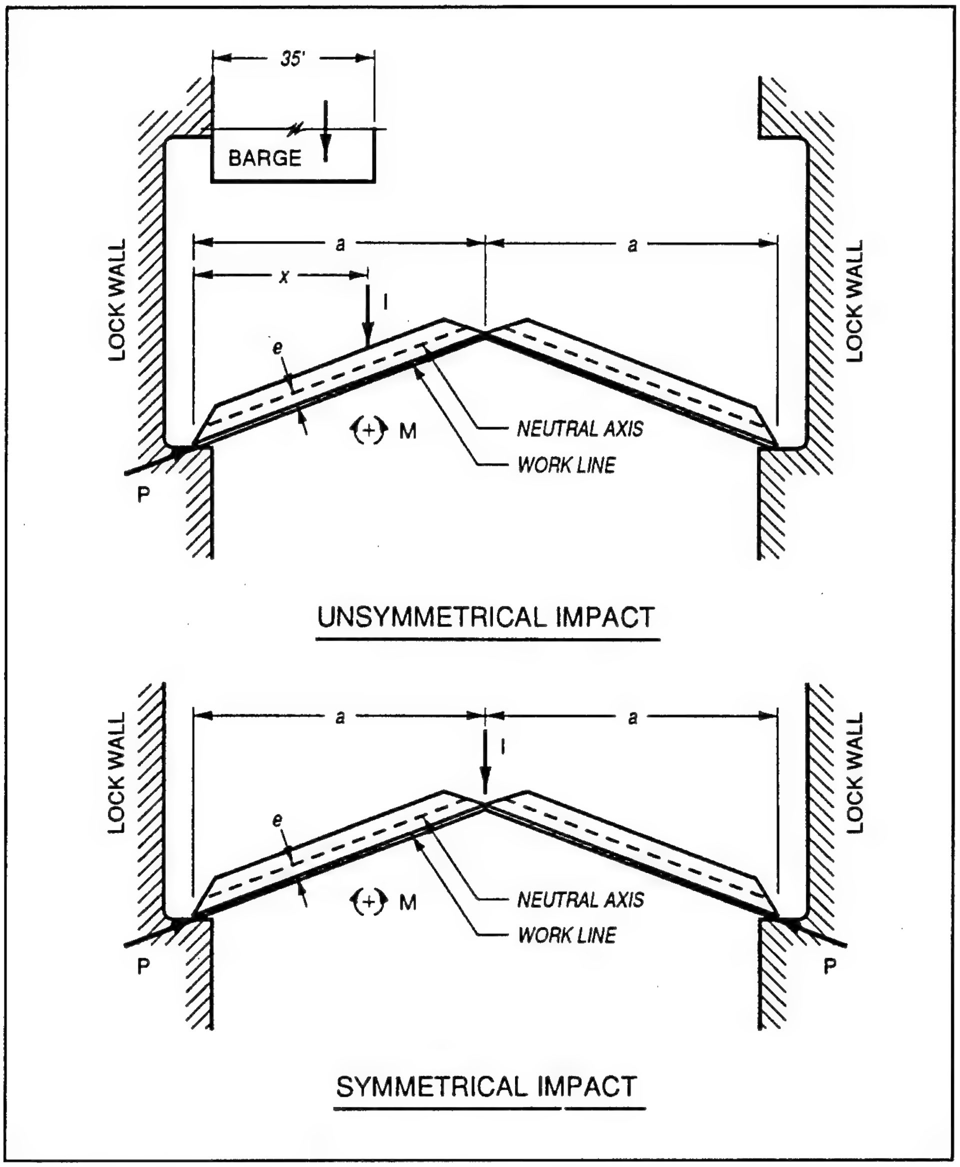


Figure 6. Impact loads for miter gate girders

The equations used to find the axial and flexure loads are

a. Symmetrical impact:

$$P = \frac{5I}{\sqrt{10}} \tag{1}$$

$$M = -Pe \tag{2}$$

b. Unsymmetrical impact:

$$P = \frac{(4x + a)I}{\sqrt{10}\, a} \tag{3}$$

$$M = \left[\frac{Ix\,(a - x)}{a}\right] - Pe \tag{4}$$

where

P = axial loads

I = impact load specified as 400 kips for symmetrical impact and 250 kips for unsymmetrical impact

M = flexure load

e = distance between work line and neutral axis of the girder

x = distance between the quoin contact point and the unsymmetrical impact load position

a = distance between quoin contact point and miter contact

Earthquake loads

Design loads are specified based on an operational basis earthquake (OBE) having a 50-percent chance of being exceeded in 100 years. This translates to a probability of annual exceedance of 0.0069, or approximately 145 years mean recurrence interval. The earthquake load is based on inertial hydrodynamic effects of water moving within the structure. This is determined based on Westergaard's equation:

$$p = \frac{7}{8}\,\gamma_w a_c \sqrt{Hy} \tag{5}$$

where

p = lateral pressure at a distance y below the pool surface

γ_w = unit weight of water (62.428 lb/ft^3)

a_c = maximum acceleration of the supporting lock wall due to the OBE (expressed as a fraction of gravitational acceleration g)

H = pool depth

The lock wall is assumed to be rigid in determination of a_c, and the assumed direction of a_c is parallel to the lock center line. The inertial forces resulting from the mass due to structural weight, ice, and mud are not included in the earthquake loads because the magnitudes of these loads are insignificant compared with the hydrodynamic loads obtained from Westergaard's equation.

Load combinations

EM 1110-2-2105 specifies that miter gates shall have design strengths at all sections at least equal to the required strengths calculated for the factored loads and forces in the following load combinations:

$$1.4H_s + 1.0I \tag{6}$$

$$1.4H_s + 1.0H_t \tag{7}$$

$$1.2D + 1.6(C + M) + 1.0H_t \tag{8}$$

$$1.2D + 1.6(C + M) + 1.2Q \tag{9}$$

$$1.2H_s + 1.0E \tag{10}$$

where

D = dead loads

Q = maximum operating load

E = earthquake load

I = barge impact loads

C = ice load

M = mud load

H_s = hydrostatic load

H_t = temporal hydraulic load

Load cases

As specified in EM 1110-2-2703, the following load cases shall be considered with the appropriate loading combinations:

a. Case 1: Mitered condition. Loads include hydrostatic loads due to upper and lower pools and barge impact or temporal hydraulic loads (Equations 6 and 7). Although not included in Equations 6 and 7, loads *C*, *D*, and *M* act when the gate is in the mitered position. However, in the mitered position, the effects of *C*, *D*, and *M* will not control the member sizes. Loads *C*, *D*, and *M* are accounted for in load Case 2 in which they may be controlling. Lateral ice loads are not considered in Equations 6 and 7 (EM 1110-2-2105). It would be appropriate to include such a load for *I* as specified by Equation 6. However, design for a lateral ice load of 5 kips/ft (as specified in EM 1110-2-2105) with a load factor of 1.0 will not control the design when compared with the design required by the impact loads.

(1) Above pool. Equation 6 is applicable to the girders located above the pool (upper pool elevation for the upper gate and lower pool elevation for the lower gate) where barge impact may occur. The skin plate and intercostals need not be designed for barge impact. For design of skin plate and intercostals located above the pool, a minimum hydrostatic head of 6 ft is assumed.

(2) Below pool. The upper gate is designed assuming that the lock is dewatered. Loads include hydrostatic loads due to upper pool only (Equation 7, $H_t = 0$). The lower gate is designed considering normal upper and lower pool elevations including temporal hydraulic load H_t. H_t is applicable only to the submerged part of the gate.

b. Case 2: Gate torsion. Loads include gravity loads (*C*, *M*, and *D*) and operating equipment load *Q* or temporal hydraulic load H_t (Equations 8 and 9). In this condition there are no differential hydrostatic loads.

(1) Temporal condition. Equation 8 is applied to consider gate leaf torsion with the temporal hydraulic load acting on the submerged part of leaf (the temporal hydraulic load may act in either direction).

(2) Submerged obstruction. Equation 9 is applied to consider leaf torsion that may be caused by a submerged obstruction. For this case, it is assumed that the bottom of the leaf is held stationary by a submerged obstruction while *Q* is applied causing the gate leaf to twist.

c. Case 3: Earthquake. Equation 10 is applied if the gate is mitered and hydrostatic loads are acting due to upper and lower pools. The earthquake acceleration is to be applied in the direction parallel to the lock center line. Elastic structural analysis should be performed with no allowance for ductility.

Analysis Procedure

The structural design specifications and analysis assumptions used in CMITERW-LRFD are according to EM 1110-2-2703, EM 1110-2-2105, AISC-LRFD (1986), and Elingwood (1993).

Procedures used to analyze and investigate the major structural elements of a horizontally framed miter gate are as discussed below.

Skin plate

The skin plate is analyzed as a rectangular flat plate with all edges fixed. A uniform load equal to the water pressure at the center of the panel under consideration is assumed to act over the entire surface.

The skin plate is to be sized using the following:

a. Yield stress criteria, where the maximum calculated stress should be less than the yield limit state of

$$\alpha \phi_b F_y$$

where

α = a reliability factor for HSS and has a value of 0.9 or 0.85 as defined earlier

ϕ_b = bending resistance factor equal to 0.9 as defined earlier

F_y = yield stress

b. Deflection criteria, where the maximum deflection allowable is $0.4t$ where t = the skin plate thickness.

c. Fatigue criteria, where the maximum calculated stress range shall be less than the allowable fatigue stress range F_r (AISC-LRFD 1986).

Stress and deflection are calculated using the following equations (EM 1110-2-2703, AISC-LRFD 1989, and Timoshenko 1959):

$$F_N = \frac{0.5\ Wb^2}{t^2 \left[1 + 0.623 \left(\frac{b}{a}\right)^6\right]} \tag{11}$$

$$\delta = \frac{0.0284\ Wb^4}{\left[1 + 1.056\left(\frac{b}{a}\right)^5\right] Et^3} \tag{12}$$

where

F_N = nominal stress ($<\alpha\phi_b F_y$ for yield stress criteria and $F_N \le F_r$ for fatigue criteria)

W = factored uniform load W_u for yield stress criteria and unfactored uniform hydrostatic loads W for fatigue criteria

t = plate thickness

a = larger plate dimension

b = smaller plate dimension

δ = deflection ($\delta < \delta_{max} = 0.4t$)

E = modulus of elasticity

The minimum size of the skin plate above the pool level should be determined using an assumed hydrostatic head of 6.0 ft (Figure 5).

Intercostals

Intercostals will be flat plates or T-sections, sized in such a manner that the maximum calculated moment is less than the nominal bending strength $\alpha\phi_b M_n$. Intercostals are configured as vertical fixed-end beams with supports at the center line of girder webs. According to EM 1110-2-2703, the intercostals may be designed as simple or fixed-end beams. An effective width of the skin plate is assumed to act with the intercostal plate or T-section, producing a T-section when interacting with a plate and an I-section when interacting with a T-section. The effective width of the skin plate on each side of the plate or T-section is calculated using the width-to-thickness ratio of $\frac{95}{\sqrt{F_y}}$. Figure 7 shows the geometry of both sections.

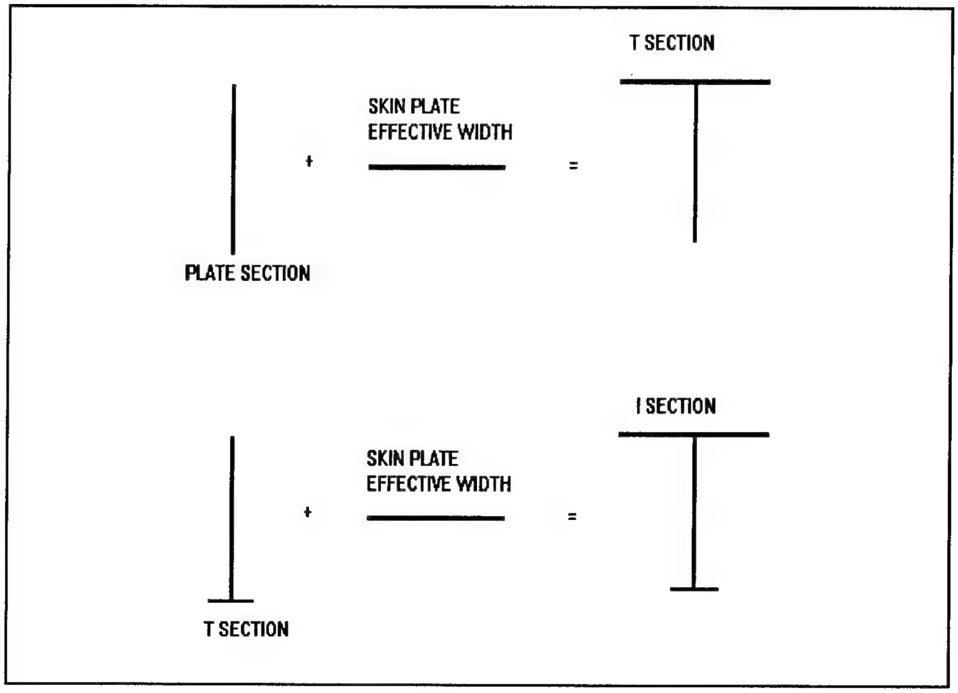


Figure 7. Intercostal sections

Assuming average water pressure, the loading begins at the edge of the girder flange or a maximum of 6 in. from the center line of the girder web. The assumed loading is applied over an area with the boundary lines being 45 deg from the point at the edge of the flange (or 6 in.), and half the distance between intercostals. These boundary lines intersect with the load line boundaries from adjacent panels at a point midway between intercostals, thereby forming an effective load area of two triangular areas, one at each end, usually with a rectangular section in the center (Figure 8). Figure 8 also shows the equations used to calculate the fixed-end moment (FEM), and the simple supported-beam moment (SBM) at the center line of the intercostals for trapezoidal and triangular loading.

The bending strength of the intercostals is the plastic moment for a simply supported beam since the compression flange is supported continuously by the skin plate. For fixed and pin ends, the bending strength can be found by use of the equations presented below:

a. For T-beams loaded in the plane of symmetry and bending about the major axis, with flange and web slenderness ratios less than the corresponding values of λ_r in Table B5.1 of AISC-LRFD (1986):

$$M_n = M_{cr} = \frac{C_b \pi \sqrt{EI_y GJ}}{L_b}\left(B + \sqrt{1 + B^2}\right) \le M_y \tag{13}$$

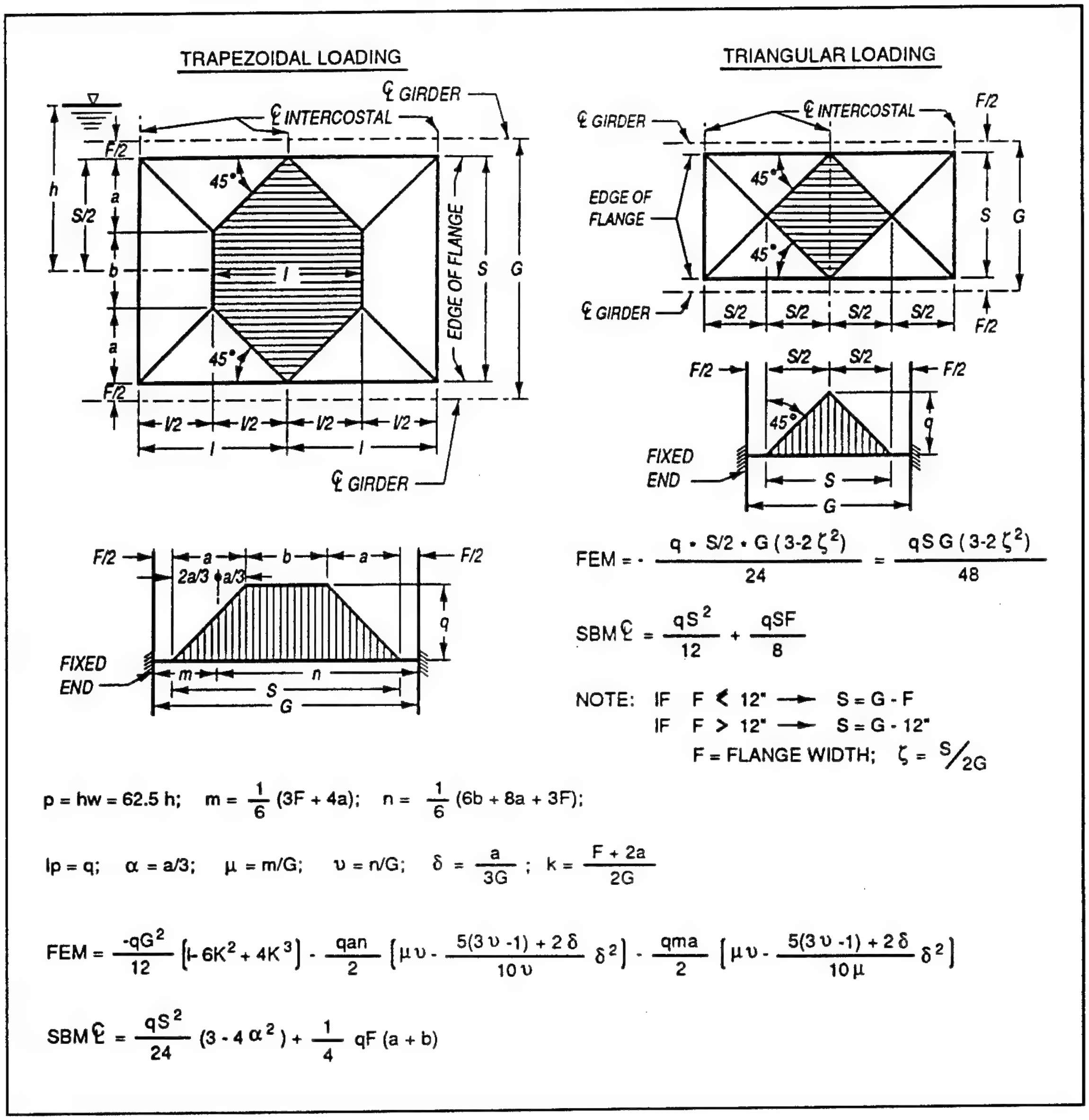


Figure 8. Intercostal loading diagram

where

$$B = \pm\, 2.3 \left(\frac{d}{L_b}\right)\sqrt{\frac{I_y}{J}} \tag{14}$$

and

M_n = nominal flexure strength

M_{cr} = critical flexure strength

C_b = bending coefficient dependent upon moment gradient. A unit value is used for intercostal design to represent the most severe loading case

E = Young's modulus of elasticity of steel (29,000 ksi)

I_y = moment of inertia about y-axis, in.^{4}

G = shear modulus of elasticity of steel, ksi

J = torsional constant, in.^{4}

L_b = laterally unbraced length

M_y = initial yield bending moment, kip-in.

d = stem height

The plus sign for B applies when the stem is in tension, and the minus sign applies when the stem is in compression.

b. For doubly and singly symmetrical I-shaped beams bending about the major axis, the nominal flexure strength M_n is the lowest value obtained according to the limit state of lateral torsional buckling, flange local buckling, and web local buckling.

The nominal flexural strength shall be calculated using the criteria discussed later in this chapter.

Horizontal girders

Horizontal girders are, in effect, a series of three hinged arches that transmit the water pressures to the lock walls through the quoin blocks. Because horizontal girders are subject to combined bending and axial loads, they should be designed through use of the beam-column criteria.

The following is a list of criteria and assumptions that are used in the design of horizontal girders:

a. Girder analysis. The basic procedure for girder analysis is to assume that each girder is isolated as an individual member. Each member is designed as a beam-column using the criteria discussed in this chapter (AISC-LRFD 1986, Elingwood 1993).

b. Axial, flexure, and shear strengths. Axial, flexure, and shear strengths are calculated using the criteria discussed in this chapter (AISC-LRFD 1986, Elingwood 1993) with the following assumptions:

(1) Upstream girder flanges are braced continuously by the skin plate. Downstream flanges are braced by vertical diaphragms to resist lateral displacement and twist of the cross section.

(2) The length of girders considering buckling about the major axis (in the plane of the web) is the distance between the quoin block and miter block l_x. The ends are assumed pinned with $K = 1.0$.

(3) The length of girders considering buckling about the minor axis is the distance between intermediate diaphragms l_y. The ends are assumed fixed with $K = 0.65$.

(4) The design strength of compression members whose elements have width-to-thickness ratios less than λ_r of Table 1 is $\alpha\phi_c P_n$ (AISC-LRFD 1986).

$$\phi_c = 0.85$$

Table 1
Width-to-Thickness Ratios

Member	Compact Section	Noncompact Section	Slender Section
Flanges	$\frac{b}{t} \le \frac{65}{\sqrt{Fy}}$	$\frac{b}{t} \le \frac{106}{\sqrt{Fyw - 16.5}}$	$\frac{b}{t} > \frac{106}{\sqrt{Fyw - 16.5}}$
Web	$\frac{h_c}{t_w} \le \frac{253}{\sqrt{Fy}}$	Not applicable	$\frac{h_c}{t_w} > \frac{253}{\sqrt{Fy}}$
Skin plate	$\frac{b}{t} \le \frac{65}{\sqrt{Fy}}$	$\frac{b}{t} \le \frac{106}{\sqrt{Fyw - 16.5}}$	$\frac{b}{t} > \frac{106}{\sqrt{Fyw - 16.5}}$

$$P_n = A_g F_{cr}$$

For $\lambda_c \le 1.5$

$$F_{cr} = (0.658^{\lambda^2 c})\ F_y \tag{15}$$

For $\lambda_c \ge 1.5$

$$F_{cr} = \left[\frac{0.877}{\lambda^2 c}\right] F_y \tag{16}$$

where

ϕ_c = compression resistance factor

P_n = nominal actual strength, kips

A_g = gross area of member, sq in.

F_{cr} = critical actual stress, ksi

F_y = specified yield stress, ksi

$$\lambda_c = \frac{Kl}{r\pi}\sqrt{\frac{F_y}{E}} \tag{17}$$

where

K = effective length factor

l = unbraced length of member, in.

r = governing radius of gyration about plane of buckling, in.

E = Young's modulus of elasticity, ksi

(5) The nominal flexure strength M_n is the lowest value obtained according to the limit state of lateral torsional buckling (LTB), flange local buckling (FLB), and web local buckling (WLB) (AISC-LRFD 1986). The flexure design strength is $\alpha\phi_b M_n$, and the nominal flexural strength M_n shall be determined as follows for each limit state (EM 1110-2-2105 and AISC-LRFD 1986):

For $\lambda \le \lambda_p$

$$M_n = M_p \tag{18}$$

For $\lambda_p < \lambda \le \lambda_r$ (for limit state of lateral torsional buckling):

$$M_n = C_b\left[M_p - (M_p - M_r)\left(\frac{\lambda - \lambda_p}{\lambda_r - \lambda_p}\right)\right] \le M_p \tag{19}$$

(for limit state of flange and web local buckling):

$$M_n = M_p - (M_p - M_r)\left(\frac{\lambda - \lambda_p}{\lambda_r - \lambda_p}\right) \tag{20}$$

For $\lambda > \lambda_r$:

$$M_n = M_{cr} = SF_{cr} \tag{21}$$

where

$$\lambda = \frac{L_b}{r_y} \text{ for LTB (lateral torsional buckling)} \tag{22}$$

$$\lambda = \frac{b}{t} \text{ for FLB (flange local buckling)} \tag{23}$$

$$\lambda = \frac{h_c}{t_w} \text{ for WLB (web local buckling)} \tag{24}$$

$$\lambda_p = \frac{300}{\sqrt{F_{yf}}} \text{ for LTB} \tag{25}$$

$$\lambda_p = \frac{65}{\sqrt{F_{yf}}} \text{ for FLB} \tag{26}$$

$$\lambda_p = \frac{640}{\sqrt{F_{yf}}} \text{ for WLB} \tag{27}$$

$$\lambda_r = \frac{X_1}{(F_{yw} - F_r)} \sqrt{1 + \sqrt{1 + X_2 (F_{yw} - F_r)^2}} \text{ for LTB} \tag{28}$$

$$X_1 = \frac{\pi}{S_x} \sqrt{\frac{EGJA}{2}} \tag{29}$$

$$X_2 = 4 \frac{C_w}{I_y} \left(\frac{S_x}{GJ} \right)^2 \tag{30}$$

$$\lambda_r = \frac{106}{\sqrt{F_{yw} - 16.5}} \text{ for FLB} \tag{31}$$

$$M_r = (F_{yw} - F_r) S_{xc} \le F_{yf} S_{xt} \text{ for LTB} \tag{32}$$

$$M_r = (F_{yw} - F_r) S_{xc} \text{ for FLB} \tag{33}$$

$$M_r = R_e F_{yf} S_x \text{ for WLB} \tag{34}$$

$$R_e = 1.0 - 0.1(1.3 + a_r)(0.81 - m) \le 1.0 \tag{35}$$

$$F_{cr} = \frac{C_b X_1 \sqrt{2}}{S_{sc} \lambda} \sqrt{1 + \frac{X_1^2 X_2}{2\lambda^2}} \text{ for LTB} \tag{36}$$

$$F_{cr} = \frac{11{,}200}{\lambda^2} \text{ for FLB} \tag{37}$$

The terms used in the above equations are:

λ = controlling slenderness parameters

λ_p = largest value of λ for which $M_n = M_p$

M_n = nominal flexural strength, kip-in.

M_p = plastic moment, kip-in.

M_r = limiting buckling moment, kip-in.

λ_r = largest value of λ for which buckling is inelastic

C_b = bending coefficient dependent upon moment gradient. (A unit value is used for girders designed to represent the most severe loading case.)

M_{cr} = buckling moment, kip-in.

S = section modulus, in.^{3}

F_{cr} = critical stress, ksi

L_b = laterally unbraced length, in.

r_y = radius of gyration about minor axis, in.

b = flange width, in.

t = flange thickness, in.

h_c = twice the distance from the neutral axis to the inside face of the compression flange less the fillet or corner radius, in.

t_w = web thickness, in.

F_{yf} = yield strength of the flange, ksi

$X_{1,2}$ = beam buckling factor

F_{yw} = yield strength of the web, ksi

F_r = compressive residual stress in flange = 16.5 ksi

S_x = section modulus

E = Young's modulus of elasticity, ksi

G = shear modulus of elasticity of steel, ksi

J = torsional constant, in.^{4}

A = cross-section area, in.^{2}

C_w = warping constant, in.^{6}

I_y = moment of inertia, minor axis, in.^{4}

S_{xc} = section modulus of the outside fiber of the compression flange, in.^{3}

S_{xt} = section modulus of the outside fiber of the tension flange, in.^{3}

R_e = hybrid girder factor

a_r = ratio of web area to compression flange area

m = ratio of web yield stress to flange yield stress or the critical stress

(6) The interaction of flexure and compression in symmetrical shapes shall be limited by the following equations (AISC-LRFD 1986):

For $\dfrac{P_u}{\alpha\phi_c P_n} \geq 0.2$

$$\frac{P_u}{\alpha\phi_c P_n} + \frac{8}{9}\left(\frac{M_{ux}}{\alpha\phi_b M_{nx}} + \frac{M_{uy}}{\alpha\phi_b M_{ny}}\right) \leq 1.0 \tag{38}$$

For $\dfrac{P_u}{\alpha\phi_c P_n} < 0.2$

$$\frac{P_u}{2\alpha\phi_c P_n} + \left(\frac{M_{ux}}{\alpha\phi_b M_{nx}} + \frac{M_{uy}}{\alpha\phi_b M_{ny}}\right) \le 1.0 \tag{39}$$

where

P_u = required compressive strength, kips

α = reliability factor for HSS

ϕ_c = resistance factor for compression, $\phi_c = 0.85$

P_n = nominal compressive strength, kips

M_u = required flexural strength, kip-in.

$M_u = B_1 M_{nt}$

M_{nt} = required flexural strength in member, assuming there is no lateral translation of the frame, kip-in.

M_n = nominal flexural strength, kip-in.

ϕ_b = resistance factor for flexure $\phi_b = 0.90$

$$B_1 = \frac{C_m}{\left(1 - \frac{P_u}{p_e}\right)} \ge 1 \tag{40}$$

$$P_e = \frac{A_g F_y}{\lambda_c^2} \tag{41}$$

where

$C_m = 1.0$

A_g = gross area of member, in.^{2}

λ_c = as defined in section to calculate axial strength of compression members

(7) The design shear strength for webs is

$\alpha\phi_v V_n$

where

$$\alpha = 0.9$$

$$\phi_v = 0.9$$

and the nominal shear strength V_n is determined as follows (AISC-LRFD 1986):

For $\dfrac{h}{t_w} \le 187 \sqrt{\dfrac{K}{F_{yw}}}$

$$V_n = 0.6 F_{yw} A_w \tag{42}$$

For $187 \sqrt{\dfrac{K}{F_{yw}}} < \dfrac{h}{t_w} \le 234 \sqrt{\dfrac{K}{F_{yw}}}$

$$V_n = 0.6 F_{yw} A_w \frac{187 \sqrt{\dfrac{K}{F_{yw}}}}{\dfrac{h}{t_w}} \tag{43}$$

For $\dfrac{h}{t_w} > 234 \sqrt{\dfrac{K}{F_{yw}}}$

$$V_n = A_w \frac{26{,}400 K}{\left(\dfrac{h}{t_w}\right)^2} \tag{44}$$

The web plate buckling coefficient K is given by

$$K = 5 + \frac{5}{\left(\dfrac{a}{h}\right)^2} \tag{45}$$

except that K shall be taken as 5, if a/h exceeds 3 or $[260/(h/t_w)]^2$. When stiffeners are not required, $K = 5$. In unstiffened girders, h/t shall not exceed 260, where

h = clear distance between flanges, in.

t_w = web thickness, in.

F_{yw} = yield strength of the web, ksi

A_w = cross-section area of the web, in.^{2}

a = clear distance between transverse stiffeners

c. *Axial, flexure, and reaction loads.* Equations to find the axial, flexure, and reaction loads are (see Figure 9 for details):

$$P1 = \frac{WL}{2} \cot \theta \tag{46}$$

$$P2 = Wt \tag{47}$$

$$P = P1 + P2 \tag{48}$$

$$M_x = \frac{W}{2} \left[Lx - La\cot\theta + (t - a)^2 - a^2 - x^2 \right] \tag{49}$$

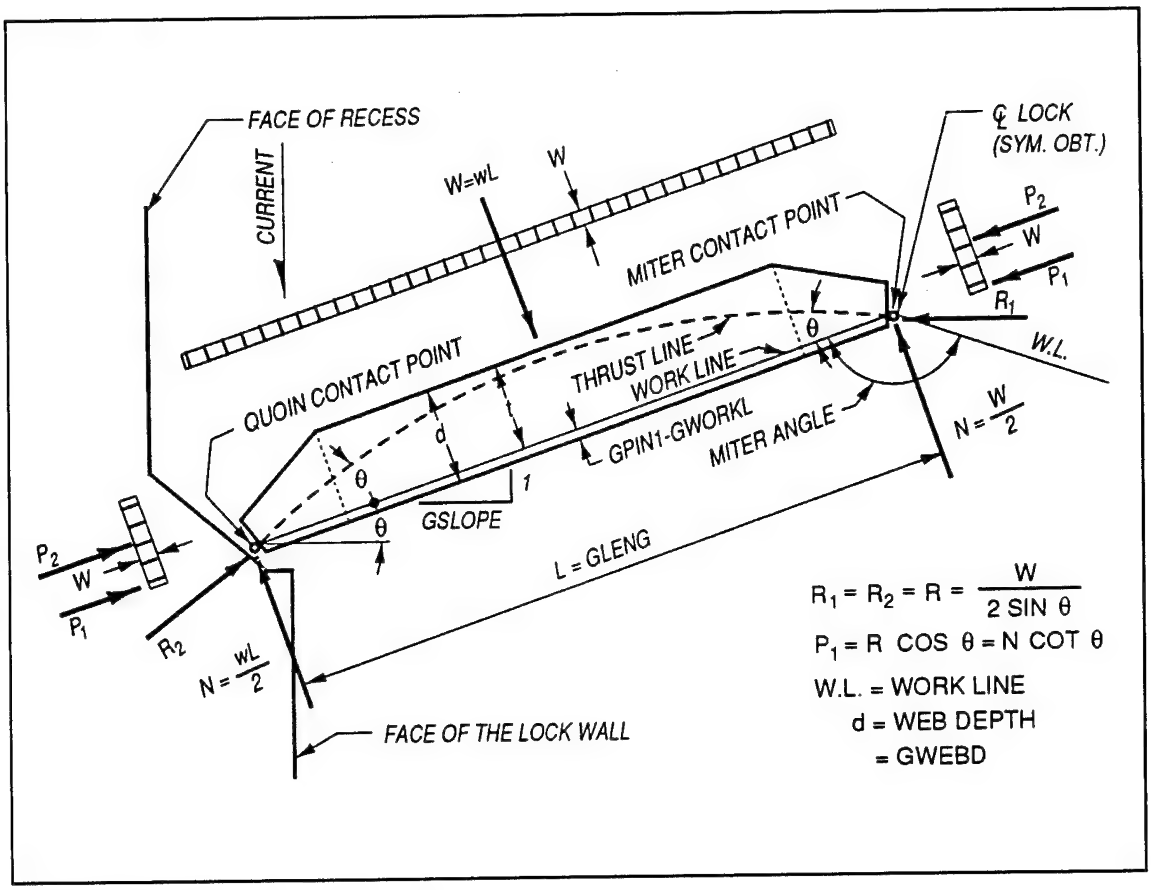


Figure 9. Girder reactions

$$N = \frac{WL}{2} \tag{50}$$

where

$P1$ = axial load due to the reaction at the lock wall

W = uniform loads

L = girder length

θ = miter angle

$P2$ = axial load due to the uniform load

t = distance between work line and the outside face of the upstream flanges

P = maximum resultant compression load

M_x = flexure load at distance x from the miter contact point

x = distance where flexural strength is calculated

a = distance between the work line and the neutral axis (work line distance is from top of downstream flange)

N = girder reaction perpendicular to the girder axial axis (maximum shear load)

d. Flange width and thickness. The minimum flange widths are to be 8 in. for upstream flanges and 12 in. for downstream flanges. The minimum thickness is specified as 3/8 in. for webs and 1/2 in. for flanges (EM 1110-2-2703). The maximum width of the flanges is limited to $24t_f$ (t_f is the flange thickness), except that downstream flanges are also limited to 24 in., reducing the possibility of the flange being undesirably wide and thin. The maximum change in flange width on the same edge of a girder web is 6 in., with a 3-in. differential on each edge of the flange except for the downstream flange of the bottom girder, where the total 6 in. of differential may be on the upper edge of the flange (Figure 10). This applies between the sections at the center line of a girder, where the upstream flange is maximum width and the downstream flange is minimum width. This also applies at a section at the end of the girder where the upstream flange is a minimum width and the downstream flange is a maximum width. The bottom girder is a special case in which the downstream flange is a maximum of 15 in. and a minimum of 9 in., with an extension below the center line of the web of 3 in. to provide additional clearance between the bottom girder and the sill. For the end section of

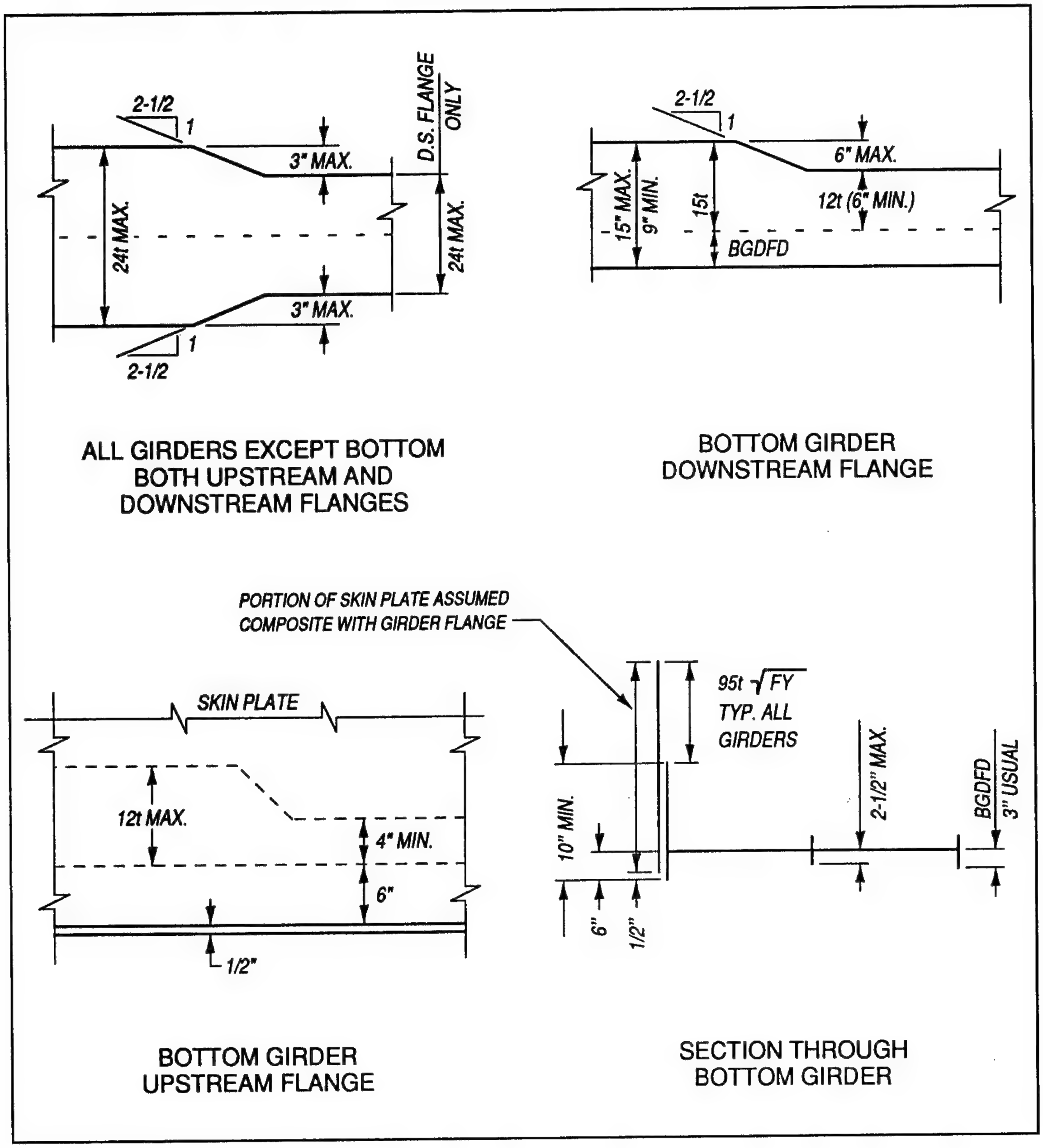


Figure 10. Girder flange data

the bottom girder, where the downstream flange is heavier, the upper portion of the flange is a maximum of $15t_f$ above the center line of the girder web.

e. Upstream flange. The upstream flange of the bottom girder should extend 6 in. below the center line of the girder web, from end to end of the girder, with the skin plate 1/2 in. above the lower edge of the flange. A minimum of 4 in. should be used above the center line of the web, thus making a minimum width of 10 in. for the upstream flange of the lower girder.

f. *Skin plate extension.* The maximum extension of the skin plate above the center line of the top girder web is 8 in., to prevent interference with the operating strut. The maximum extension of the skin plate above the top flange is 1/2 in., limiting the maximum width of the upstream flange of the top girder to 15 in.

g. *Skin plate width.* An effective portion of the skin plate is assumed to act with the upstream flange. The effective width of the skin plate next to each edge of the upstream girder flange is based on a width-to-thickness ratio consistent with design assumptions (assumption of compact or noncompact section).

h. *Webs.* Webs are designed using requirements for uniformly compressed stiffened elements. The use of slenderness parameters for webs in combined flexure and axial compression in Table B5-1 of AISC-LRFD (1986) should be avoided since these criteria were developed for rolled shape beam columns and may not apply for deep girder sections.

i. *Ratio values.* The ratio values for compact, noncompact, and slender sections are shown in Table 1.

Tapered end section

The tapered end sections of girders are analyzed in a manner different from that used to analyze girder sections with full web depths. The moment is determined assuming a cantilever section of length Z' with a uniform water load plus the moment created by the girder reaction being eccentric from the centroid of the section (Figure 11).

The critical point is at a distance Z' from the end of the web. Z' is equal to one-half the smaller span between adjacent girders (above and below) to the web under consideration, minus eight times the thrust diaphragm thickness. If eight times the thrust diaphragm thickness is greater than one-half the smaller adjacent span, the value of Z' becomes negative, and the minimum section for the tapered web is taken as the web width at the end of the web, with one-half the height of the thrust diaphragm and the appropriate upstream and downstream girder flanges. The maximum width of flanges shall be $24t_f$, reducing the possibility of the flange being undesirably wide and thin. Figures 11 and 12 show the distribution of the loads in the tapered section and the locations for which the stresses are calculated.

End diaphragm

End diaphragms, often called quoin and miter diaphragms, are designed as a panel acting as a skin plate, with the effective panel being between the stiffener angle and the next lower girder. The stiffener is at the midpoint between the girders. Design loads are the hydrostatic head at the center of the effective panel

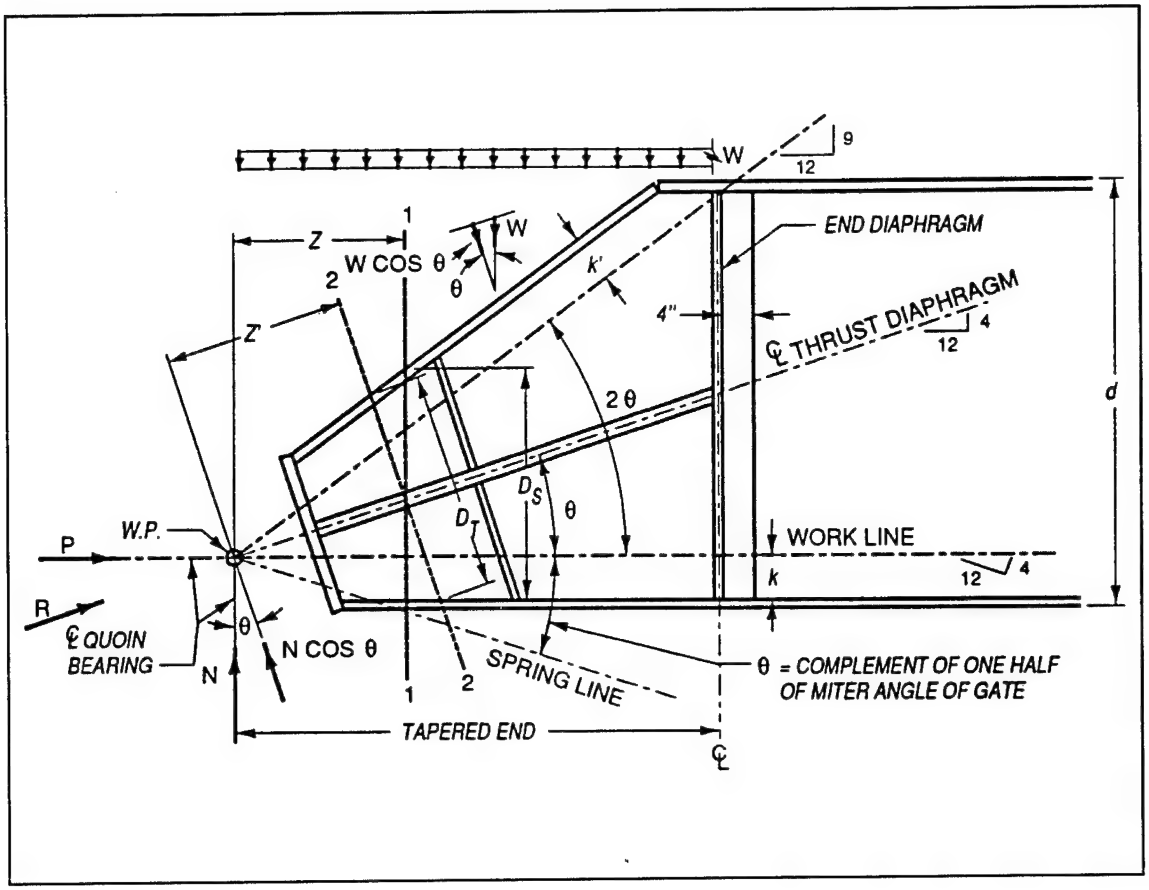
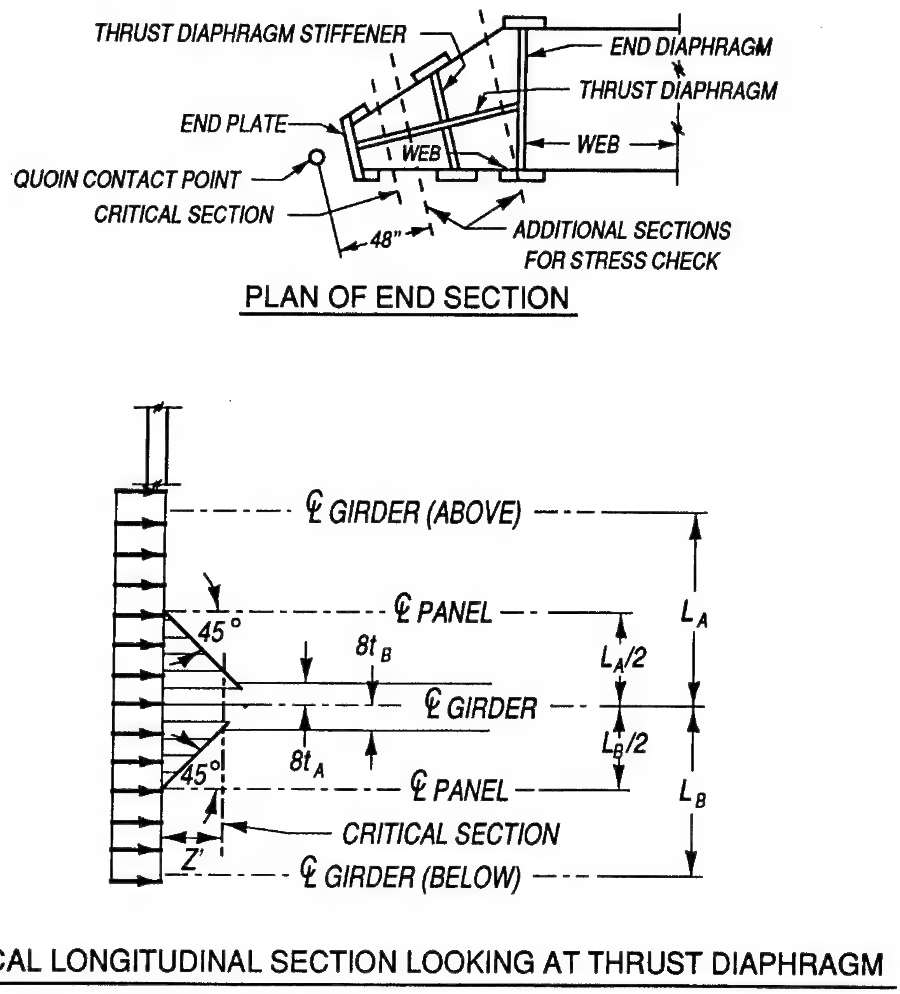


Figure 11. Tapered end critical section

and the reactions produced by the diagonal prestress loads. Each end diaphragm, between girders, is divided into four panels subjected to the water pressure. Four panels are surrounded by the girder webs, vertical flange at the skin plate, the thrust diaphragm, and the horizontal end diaphragm stiffener. The panels are assumed fixed on all four edges and designed by use of the same formulas that were applied to the skin plate. The end diaphragm stiffeners are assumed fixed at the upstream end and at the center line of the thrust diaphragm. The diaphragm load is triangular on the ends, with the boundary lines 45 deg from the vertical at the point of the triangle, this point being the center line of the thrust diaphragm and the upstream ends of the stiffener (Figure 13). A part of the end diaphragm shall be assumed effective with the stiffener, with the effective width equal to $\frac{95}{\sqrt{F_y}}$ on each side of the angle.

t_A = THICKNESS OF THRUST DIAPHRAGM ABOVE GIRDER
t_B = THICKNESS OF THRUST DIAPHRAGM BELOW GIRDER



$Z'_A = L_A/2 - 8t_A \qquad Z'_B = L_B/2 - 8t_B$

Z'_A AND Z'_B MUST BE POSITIVE

Z' = IF 8t IS GREATER THAN $\frac{L_A}{2}$ OR $\frac{L_B}{2}$

FOR $L_A = L_B = L$ AND $t_A = t_B = t$

$Z' = L/2 - 8t$

$Z = Z' \cos \Theta$

Figure 12. Tapered end load distribution

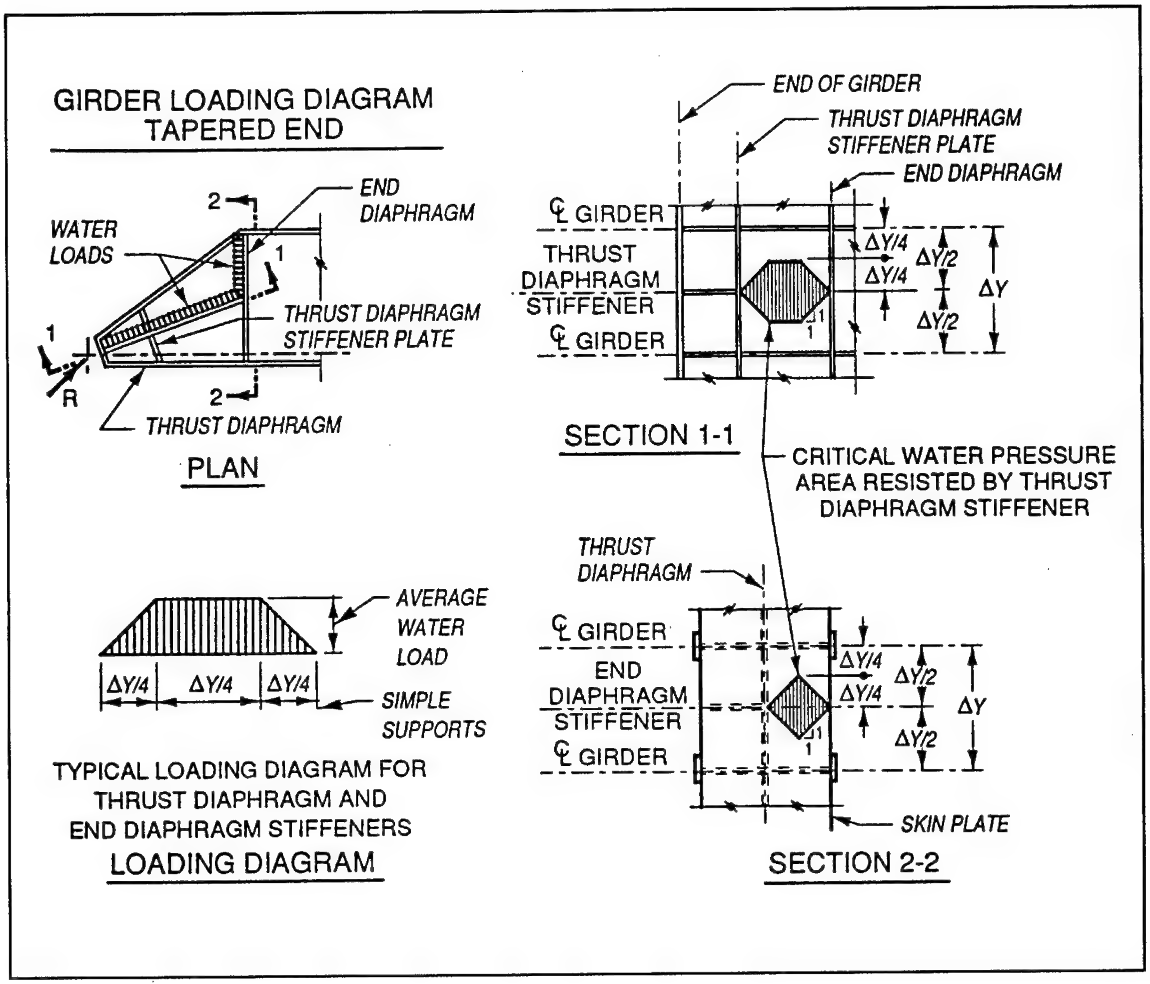


Figure 13. Diaphragm loads

Thrust diaphragm

The thrust diaphragm is tangent to the thrust curve of the gate at the contact points and is approximately in line with the thrust curve between the contact points and the end diaphragm, which is the limit of the thrust diaphragm. The thrust diaphragms will distribute the reactions of the girder web into the quoin block and also serve as a damming surface between the end plate and the end diaphragm. Part of the thrust diaphragm is also considered effective in the quoin post, making it subject to bearing, skin plate, and column action stresses. Shear stress is to be checked also, but is not combined with the listed forces. The analysis is based on combined axial load from the girder reaction and bending from water damming pressure (Figure 13), which has to be less than or equal to the lesser value of the yield stress or the elastic-limit stress. The flexure stress produced by the damming water pressure can be determined using the skin plate equations (Equation 12), and the axial load is determined as follows (Figure 14):

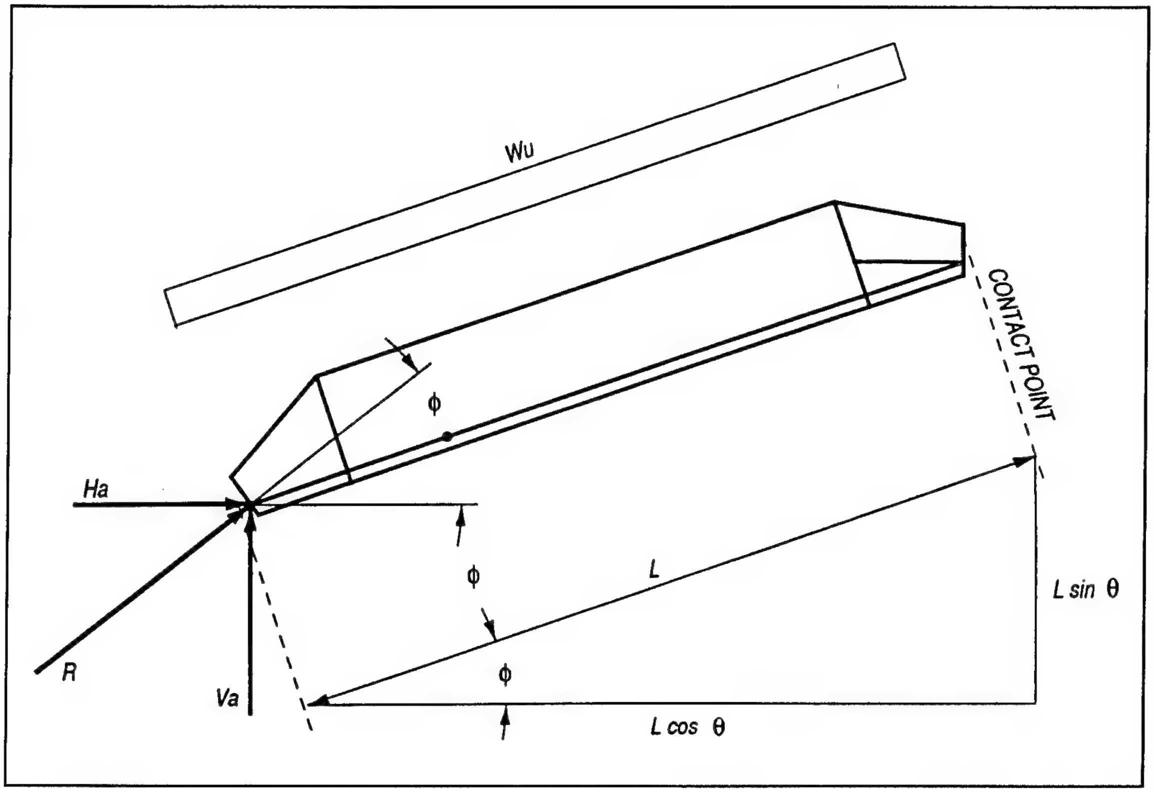


Figure 14. Thrust diaphragm, axial load calculation

a. Determine actual load V_a.

$$\theta = zeta$$

$$V_a = W_u L \cos \theta \tag{51}$$

b. Determine H_a using summation of moments in contact point equal to ($\Sigma M_{cp} = 0$).

$$H_a = \frac{V_a L \cos \theta - \frac{W_u L^2}{2}}{L \cos \theta} \tag{52}$$

c. Determine axial load R.

$$R = V_a \sin 2\theta + H_a \cos 2\theta \tag{53}$$

The elastic limit can be found by assuming that the panel under consideration is clamped on all edges and that equal uniform compression exists on two opposite edges, with the critical stress equal to

$$K \frac{E}{1 - \mu^2} \left(\frac{t_d}{b} \right)^2 \tag{54}$$

where

$K = 7.7$ when $a/b = 1.0$

$K = 6.7$ when $a/b = 2.0$

$K = 6.4$ when $a/b = 3.0$

a = longer dimension of panel

b = shorter dimension of panel

μ = Poisson's ratio

t_d = thrust diaphragm thickness

Quoin post

A section of the thrust diaphragms, vertically from top to bottom girders and horizontally from the contact plate to a point $\frac{95}{\sqrt{F_y}}$ beyond the thrust diaphragm stiffener plate, forms a column to support the dead weight of the leaf. The end plate and two vertical stiffeners form one flange of the column. The other flange is formed by a plate perpendicular to the thrust diaphragm, with vertical stiffeners on the outside edges. Figure 15 shows a typical layout of the quoin post.

The axial load of the quoin post consists of the dead weight of the leaf, plus the ice and mud load. Due to the eccentricity of the pintle and gudgeon pin with respect to the centroid of the quoin post, the quoin post is subjected to axial and bending loads and to the skin plate action of the thrust diaphragm. The following symbols and equations are used to find the combined loads in the quoin post:

$$M_x = Pe_y \tag{55}$$

$$M_y = Pe_x \tag{56}$$

$$\sigma = \frac{P}{A} + \frac{M_x}{I_x} C_y + \frac{M_y}{I_y} C_x \tag{57}$$

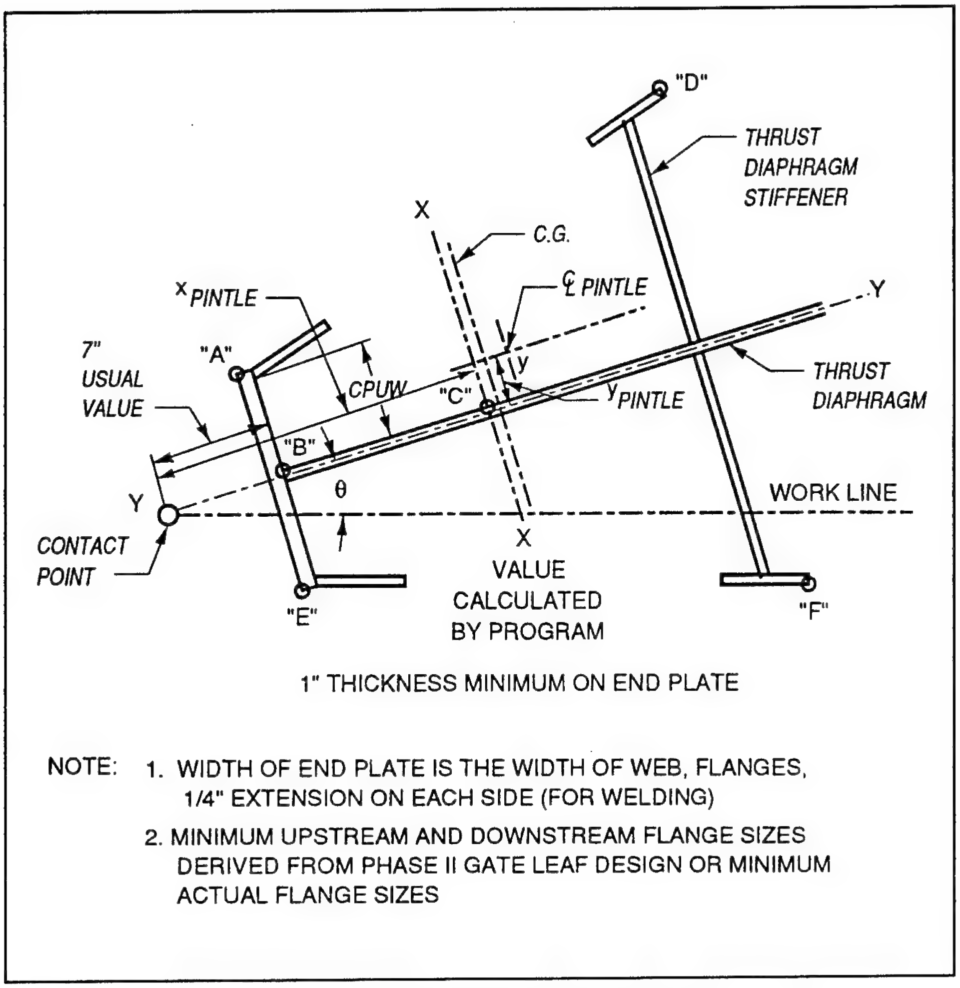


Figure 15. Quoin post layout

where

P = total axial load (dead weight plus ice and mud)

e_x, e_y = eccentricity distance from centroid of entire quoin post cross section to (inclined) action line of pintle reaction

C_x and C_y = extreme fiber distance

Diagonals

A gate is a deep cantilever girder with a relatively short span. The skin plate is the web of the girder. If the ordinary equations for the vertical deflection of a cantilever submitted to shearing and bending stresses are applied, the values obtained will be low. This happens because the skin plate imparts such a great vertical stiffness to the leaf. The stresses in the diagonals are a function of only

the torsional (twisting) forces acting upon the leaf. These forces produce a considerable torsional deflection when the gate is being opened or closed.

The shape of the twisted leaf is found geometrically. Then the work done by the loads is equated to the internal work realized by the structure. From this, the resistance offered by each diagonal to twisting of the leaf is calculated as a function of the torsional deflection of the leaf and the dimensions of the structure.

The procedure and equations required to design the diagonal elements are as follows (EM 1110-2-2703):

a. Stiffness. Evaluate the stiffness of the leaf in deforming the diagonal A'. Until more test data are available, it is suggested that A' be taken as the sum of the average cross-sectional areas of the two vertical and horizontal girders which bound a panel times 1/8 for welded horizontally framed leaves with skin of flat plates.

b. Elasticity. Evaluate the elasticity constant of the leaf without diagonals Q_o.

$$Q_o = 4E_s \sum \left(\frac{J}{H} + \frac{J}{v} \right) \tag{58}$$

where

E_s = shearing modulus of elasticity

J = modified polar moment of inertia of the horizontal and vertical members of the leaf

H = distance between top and bottom girder

v = distance from center line of the pintle to extreme miter end of the leaf

c. Location of shear center.

$$X = - \frac{b}{I} \sum a y y_n \tag{59}$$

$$Y = \frac{\sum I_n y}{\sum I_n} \tag{60}$$

where

X, Y = coordinates of shear center

b = distance from the center line of the skin plate to the downstream flange of a horizontal girder

I = moment of inertia of the gate leaf about the vertical axis

a = cross-section area of that part of the horizontal girder that lies outside the midpoint between the skin plate and the downstream flange

y = distance to any horizontal girder from the horizontal centroid axis of a vertical section through the leaf

y_n = distance to any horizontal girder from the horizontal shear center axis of a vertical section through a leaf

I_n = moment of inertia of any horizontal girder about its vertical centroid axis

d. Load torque areas.

e. Ratio of change. Calculate the ratio of change in length R_o of diagonal to deflection of leaf when diagonal offers no resistance. R_o is positive for positive diagonals and negative for negative diagonals.

$$R_o = \frac{2wt}{v\sqrt{(w^2 + h^2)}} \tag{61}$$

where

w = width of the panel enclosing diagonals

t = distance from center line of skin plate to center line of diagonal

v = distance from center line of the pintle to extreme miter end of the leaf

h = height of panel enclosing diagonals

f. Required size of diagonals.

$$A = -\frac{\Sigma Tz}{sR_o hv} \tag{62}$$

where

A = cross-section area of diagonal

Tz = torque area (product of the torque T of an applied load and the distance z to the load from the pintle; z is measured horizontally along the leaf. Tz is positive if the load produces a positive deflection).

s = design strength for tension members ($s = \alpha\phi P_n$), which is the lower value of the following:

(1) For yield in the cross section, $\alpha = 0.9$ and $\phi = 0.9$

$$P_n = F_y A_g$$

(2) For fracture in the net section, $\alpha = 0.9$ and $\phi_t = 0.75$

$$P_n = F_u A_e = F_u (U A_g)$$

g. Ratio. Evaluate the ratio R of the actual change in length of diagonal to deflection of the leaf. R is positive for positive diagonals and negative for negative diagonals.

$$R = \frac{A'}{A + A'} R_o \tag{63}$$

h. Elasticity. Evaluate the elasticity constant of a diagonal Q.

$$Q = \frac{R R_o E A h v}{L} \tag{64}$$

where

E = bending modulus of elasticity

L = length of a diagonal, center to center of pins

i. Deflection of leaf. This value is the minimum prestress deflection D_{min}

$$\Delta = \frac{\Sigma Tz}{Q_o + \Sigma Q} \tag{65}$$

j. Prestress deflection in diagonals D_{max}. D is the deflection of the leaf required to reduce the stress in a diagonal to zero. D is always positive for positive diagonals and negative for negative diagonals.

$$D = \frac{sL}{RE} + \Delta \tag{66}$$

k. Stresses during normal operation of the gate. The value of D must be between the minimum and maximum value.

$$s = \frac{RE}{L} (D - \Delta) \tag{67}$$

3 Program CMITERW-LRFD General Description

Scope

This chapter presents the installation procedure, a general description of the program, the analysis sequence of each module (recommended design, design, and investigation), how the program handles files, and how to use the on-line help.

Installation

The following sequence should be used to install the CMITERW-LRFD program:

a. Insert setup disk in a floppy disk drive.

b. In Windows File Manager or Program Manager, click File, and then Run.

c. Type the drive letter, followed by a colon (:) and a backslash (\), and the word "setup." For example:

    a:\setup

d. Follow the instructions on your screen.

Minimum Program Requirements

To run the CMITER-LRFD Windows version you will require the following as a minimum.

a. An IBM (386) or compatible computer.

b. 1.0 mb of memory (RAM) to run Windows 3.1 in standard mode and 2.0 mb of memory to run Windows 3.x in the 386 enhanced mode.

c. 1.2-mb or 1.4-mb floppy disk drive.

d. Microsoft Windows 3.1.

e. A mouse compatible with Microsoft Windows.

f. A monitor (color or monochrome) with a display adapter supported by Windows. A resolution of 640 x 480 (16 colors) must be used.

Description

CMITERW-LRFD is a computer program used to design and investigate horizontally framed miter gates using the load and resistance factor design (LRFD) criteria. The CMITERW-LRFD is a Windows version that includes a graphic interface that allows the user to generate the input files required to run each module by the presence of graphics and sketches. The interface provides the ability to edit an existing input file. The program also includes a graphic postprocessor that allows the user to see the program results graphically.

CMITERW-LRFD can be run using a mouse, the keyboard, or both. When the program is started, CMITERW-LRFD opens the main screen shown below (Figure 16):

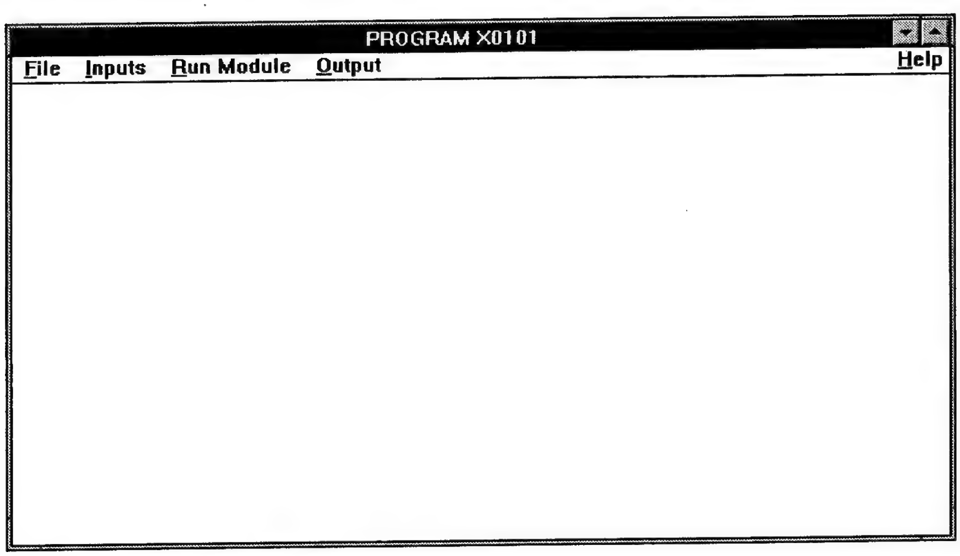


Figure 16. CMITERW-LRFD main window

The main window includes the following options:

File

The file option allows the user to open an existing file to edit or run, start a new run, save the input files created using the **Inputs** option, and terminate the program. Options are explained in detail later in this chapter.

Input

The input option may be used to generate the input files interactively as well as to edit an existing input file that has been read using the **Open** option. Chapter 4 presents a detailed explanation of the input files.

Run

CMITERW-LRFD is organized with three distinct functions to design and investigate horizontally framed miter gates (Figure 17). The three functions of the CMITERW-LRFD program are separated into three different modules: recommended design module (RECDES), design module (DES), and investigation module (INV). Each module executes one primary task and requires a data file that may be created either with the graphic preprocessor or a text editor. Modules may be used interactively. Results will be stored in a file that can be analyzed by use of the graphic preprocessor or a text editor. Run option will let the user run the RECDES, DES, or INV module. The user should answer the questions during the running time with the corresponding values for the specific problem. Chapter 5 presents a detailed explanation of how each module should be executed.

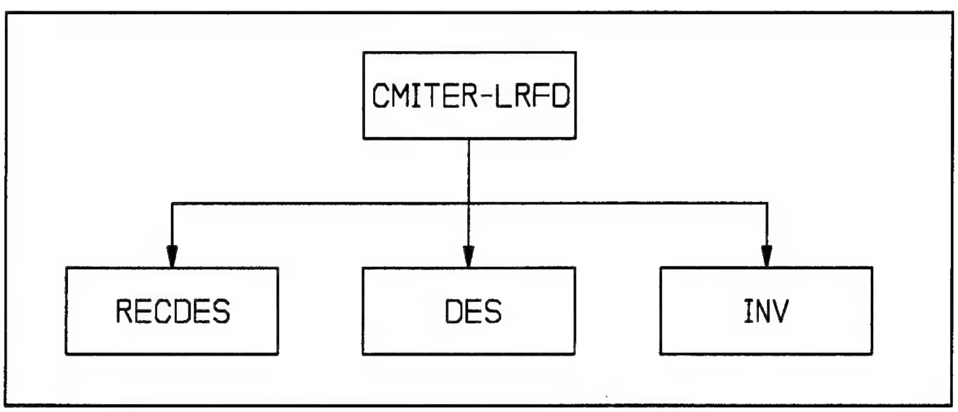


Figure 17. CMITERW-LRFD program organization

RECDES. For miter gate design, a trial-and-error process is required to find some basic dimensions that are necessary to start the design. The RECDES module performs calculations that will help to establish meaningful values. However, the selection of the basic dimensions requires the designer's judgment. The dimensions calculated by the RECDES module include a range of girder web depths, girder spacing for equal loads in each girder, and suggested spacing and sizes for intercostals. Dimensions are selected to achieve a minimum weight of the gate for the specified load combination. An advantage gained from using this module is that with a minimum amount of known data, the designer will have a choice of required values to start the design process (Figure 18).

For any girder location requested by the user, the RECDES module performs a preliminary design for the web, stiffeners, and flanges for an array of girders with web depths varying over a specific range. The ratio of the depth of girder web to the length of the leaf varies from 1/8 to 1/15 (EM 1110-2-2703). For various web depths, RECDES specifies the most economical dimension for the girder elements (based on least weight). A graph showing the variation of the girder weight with web depth can either be observed on the screen or printed.

Three factors influence the design of intercostals located at various elevations in a gate leaf: the hydrostatic load; the composite interaction between the skin plate and intercostals; and the spacing of the intercostals. The RECDES module

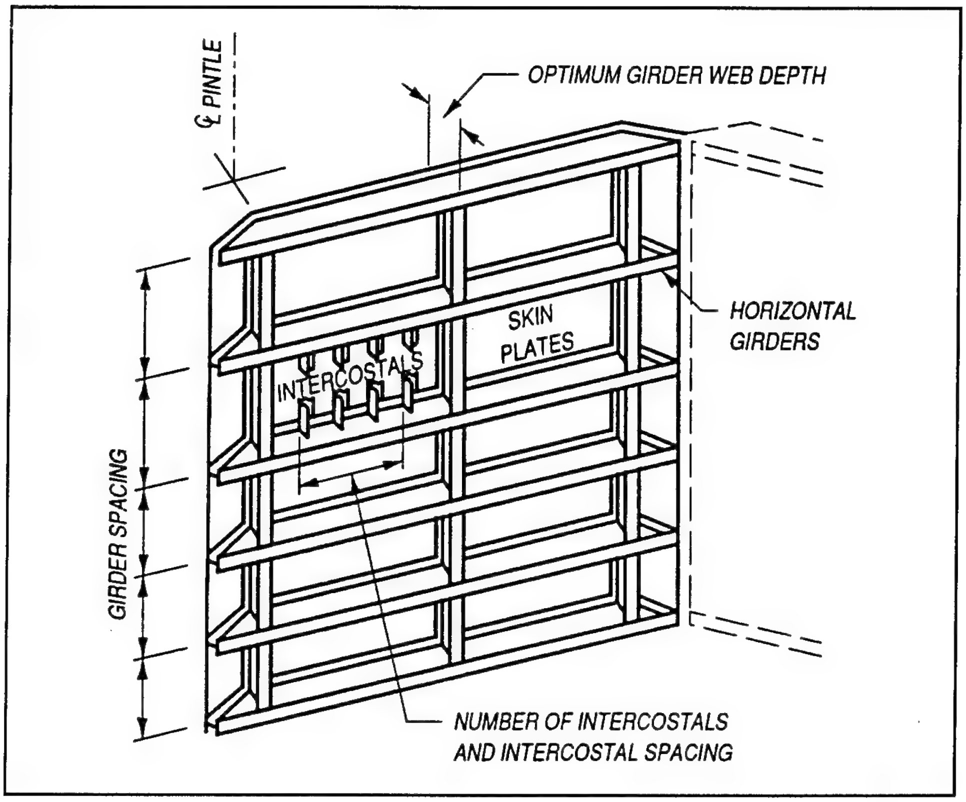


Figure 18. Downstream view of the gate; values calculated by RECDES module

will calculate and print a table showing the panel weight for different numbers of intercostals. This information enables the designer to select the best panel designs for the gate.

DES. The design module performs calculations to design the various components of a gate leaf. Basic geometry is chosen by the designer after the designer has considered the results of the RECDES module. The designer has the alternative to design either the basic structural elements (which comprise most of the weight of the gate) or the basic and detailed structural elements (Figures 1 and 2).

INV. The investigation module can be used to investigate an existing gate leaf or to verify a design for ASD or LRFD criteria. This module compares the existing strength with the required strength of the specified sections subject to appropriate load combinations or load cases. The user has the alternative of investigating either the basic structural elements or the basic and detailed structural elements (Figures 1 and 2).

Output

This option provides graphical displays that show the geometric input file values and the results of the output file for each module. Chapter 5 presents a detailed explanation of the output files.

Help

This option provides help on the execution of the program. This option will be explained in detail later in this chapter.

Analysis Sequence

The analysis sequence for the RECDES, DES, and INV is generally as follows:

a. RECDES.

(1) Select data for input girders, diaphragms, and intercostal spacing.

(2) Design skin plate panels, intercostals, and compute girder loads for the selected geometry.

(3) Design girders for several different web depths.

(4) Review results using the graphic postprocessor, edit the input file if necessary, and re-execute the module.

(5) Repeat the above steps until the specified uniform load and spacing of the girders are close to the uniform load and spacing calculated by the program. The intercostal spacing and size can also be checked.

b. DES and INV.

(1) Select input data from RECDES output files.

(2) Design or investigate intercostals, horizontal girders, skin plate, tapered end section, end diaphragms, and thrust diaphragms.

(3) Execute quoin post investigation.

(4) Execute diagonal design or investigation.

(5) Repeat above if necessary.

Working With Files

Files are managed in the CMITERW-LRFD by the **File** option shown in Figure 19. The file option includes the following choices:

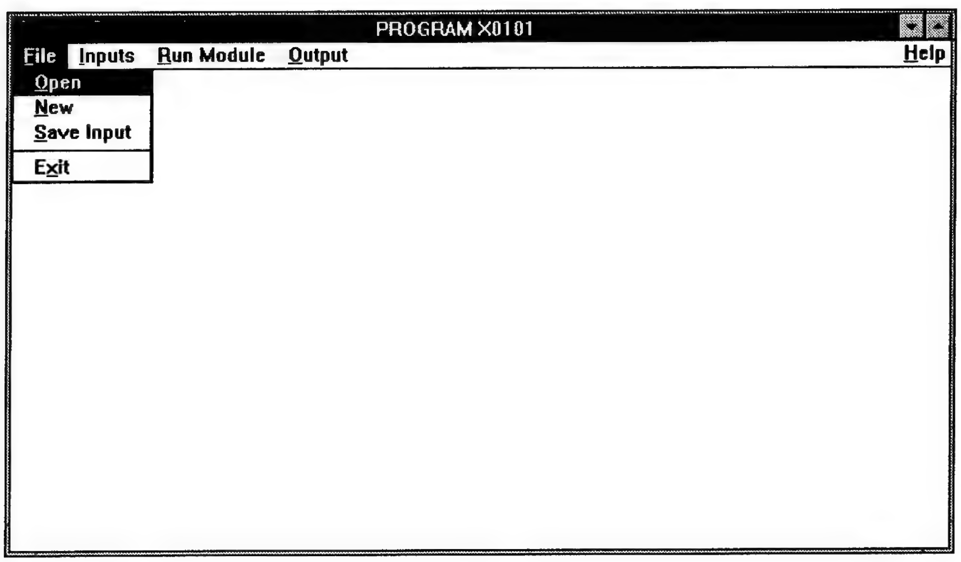


Figure 19. CMITERW-LRFD File option

a. *Open.* This option allows the user to read an existing input file that can be edited. Figure 20 shows the window that will appear when Open option is selected. As shown in the Figure 20, a window asking for the input file name will appear. This window will look for any file with *.dat extension in the directory where the program was intalled. The user can move to

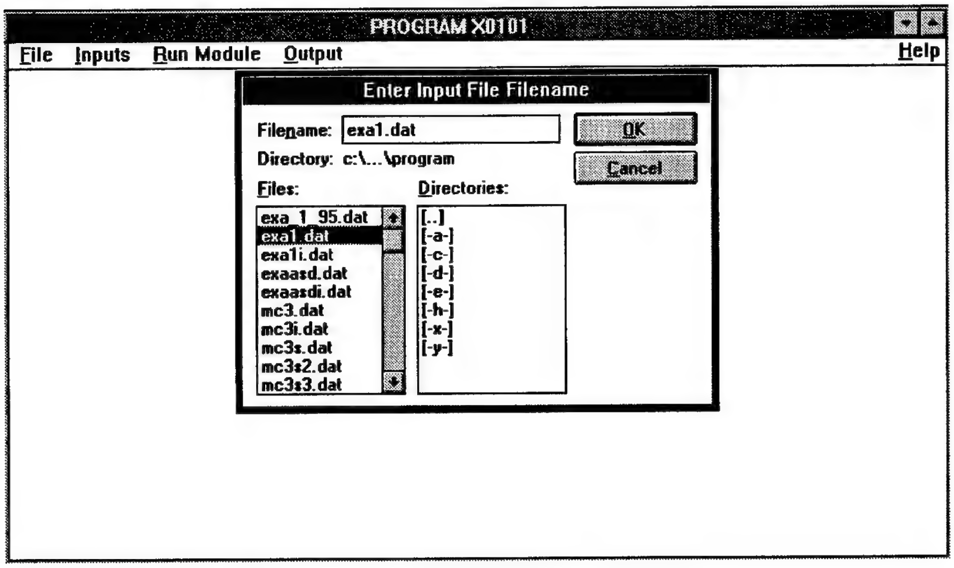


Figure 20. Input file name window

different directories in the hard disk and to any external driver. After finding the directory where the input file is located, the user should select the file by clicking with the mouse in the file desired and pressing **OK** to continue. The user may also double click the selected file to activate the desired file and continue.

b. New. This option allows the user to start a new design section without exiting the application.

c. Save Input. This option allows the user to save an input file after creating or editing it. Figure 21 shows the window that will appear when the Save input option is selected. As shown in Figure 21, the user has to select which data groups will be saved. Data groups are defined in Chapter 4. By default, Data Group 1 will be active. The window also provides the name of the file that has been edited. If a new file has been created, the box with the file name will be empty. After the selection of data groups, the user should press **OK** to continue. Figure 22 will follow asking the file name and directory where the file will be saved.

d. Exit. This option terminates the program and returns to program manager.

Using On-line Help

The user can access help from almost everywhere in the program by clicking on an item (or tabbing to it) and pressing the F1 key. Another way to get help is to press the SHIFT-F1 key combination, and then click the mouse cursor on the

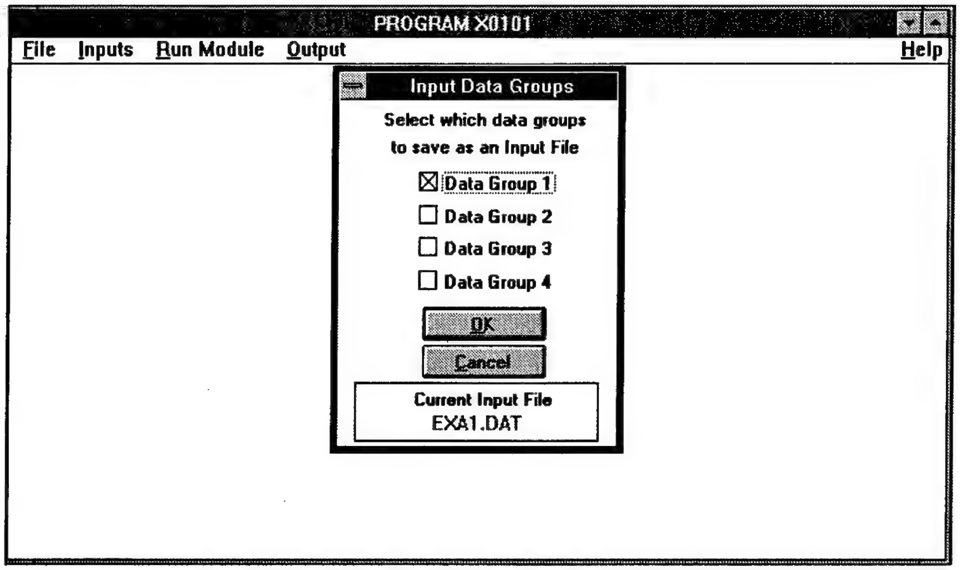


Figure 21. Data groups to be saved

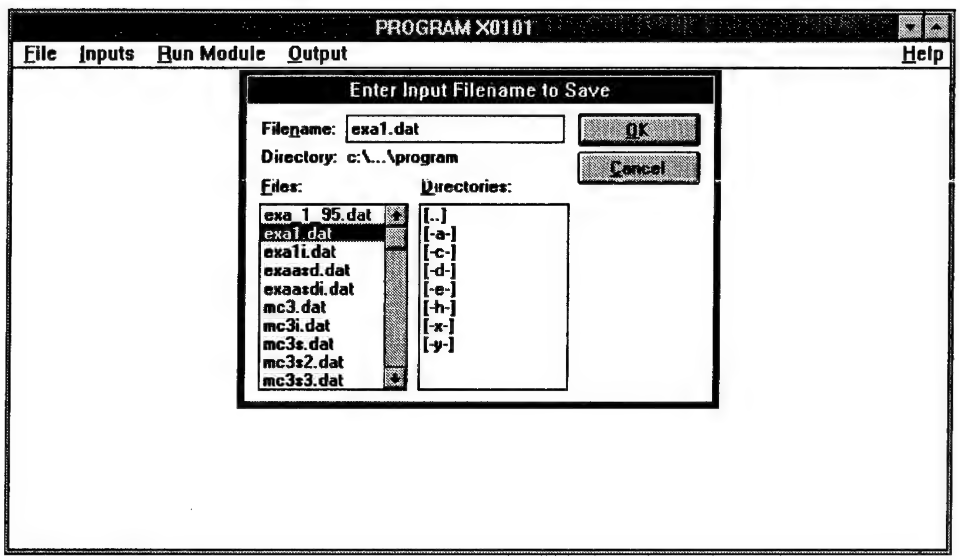


Figure 22. Input file name to be saved

item on which the user wants help. When the user sees the "Question mark - Arrow" cursor, he will be in "Help Mode," and the next item the user clicks on will bring up Windows Help.

4 CMITERW-LRFD Input Files Graphic Interface

Scope

The data file for CMITERW-LRFD is divided into four groups that will be explained in this chapter. Group 1 data are always required, whereas Groups 2 and 3 data are for a detailed design or investigation. Group 4 data are used to change the default values. CMITERW-LRFD provides a graphic interface that allows the user to create the input files with graphics. However, input files can also be created using a text editor. This chapter presents the graphic interface to create each data group. The format to create the data groups using a text editor is presented in Appendix A. When the graphic interface is used, the input file will be saved with the format presented in Appendix A. Table 2 shows the data group combinations required to run RECDES, DES, and INV modules.

Table 2
Data Group Combinations

Data Groups				
1	**2**	**3**	**4**	**Description**
Recommended Design Module (RECDES)				
X				RECDES with default values
X			X	RECDES with different default values
Design Module (DES)				
X				Design of the basic structural elements
X			X	Design of the basic structural elements with different default values
X		X		Design of the basic and detailed structural elements
X		X	X	Design of the basic and detailed structural elements with different default values
Investigation Module (INV)				
X	X	X		Investigation
X	X	X	X	Investigation with different default values

Group 1

Group 1 provides the general geometry and loads information. Group 1 is required to run the RECDES, DES, and INV modules. Figure 23 shows the data items of Group 1. As stated above, Group I is the only data group required to run the RECDES.

The following paragraph explains each variable in Group 1. The x-coordinates are measured from the gate contact point toward the miter contact point in a direction parallel with the girder working line. The z-coordinates are measured upstream from the downstream edge of the girder web in a direction perpendicular to the work line.

To start the graphic interface for data Group 1, the user should select **Group 1** from the **Input** option (Figure 24).

Figures 25 through 35 show the windows sequence describing Group 1.

Job description entry

The window shown by Figure 25 may be used to provide a general description of the problem (five lines maximum). The user should press **OK** to continue or **Previous** to return to the previous window.

Leaf geometry input window

The window shown by Figure 26 may be used to input the leaf overall geometry and the girder common geometry. The input box is red with a short definition of the variable in the bottom line, while the other boxes are blue. The user should press <Enter> to move to the next box or click with the mouse to the box desired. After all the input is finished, the user should press **Accept** to continue.

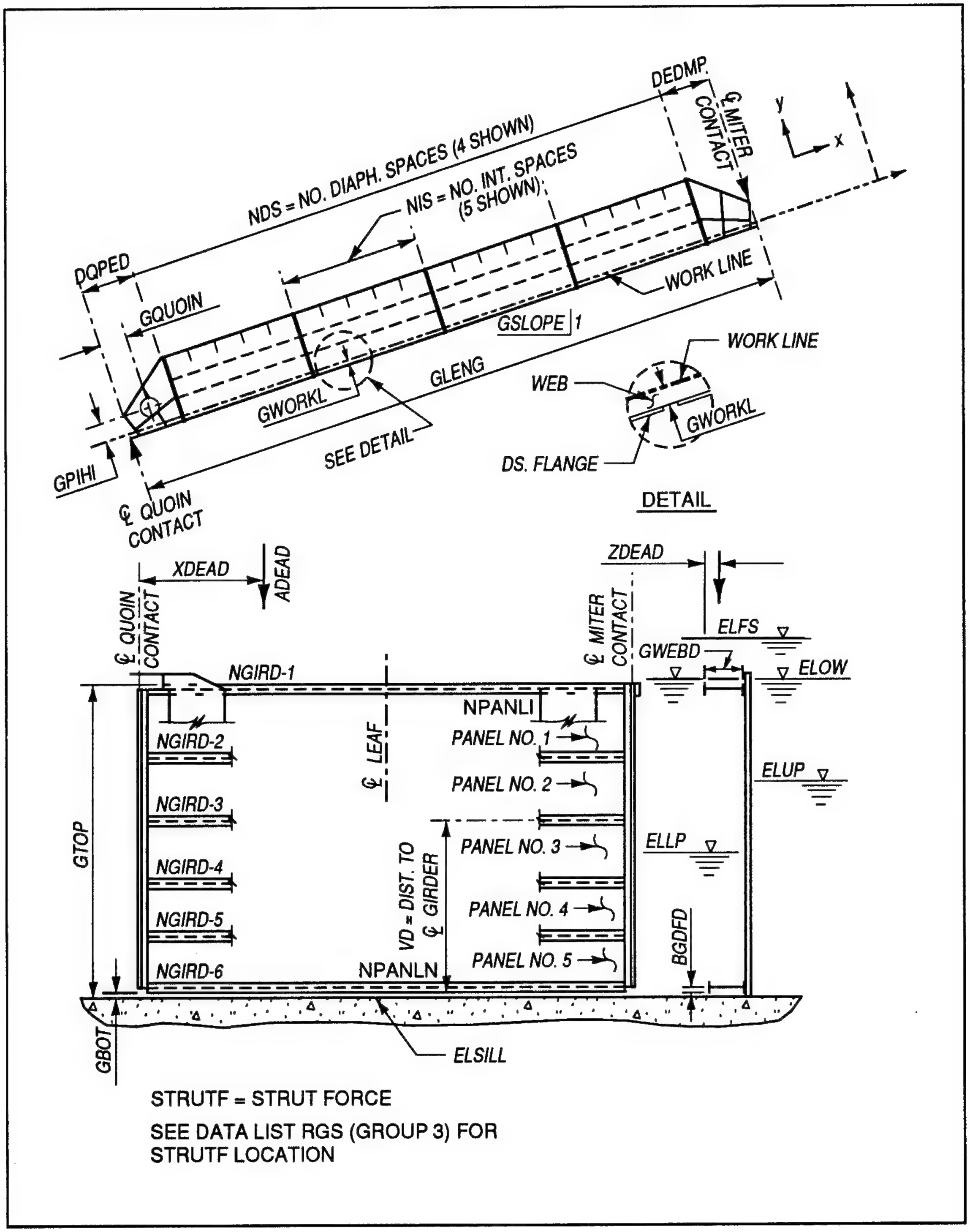


Figure 23. Data items, Group 1

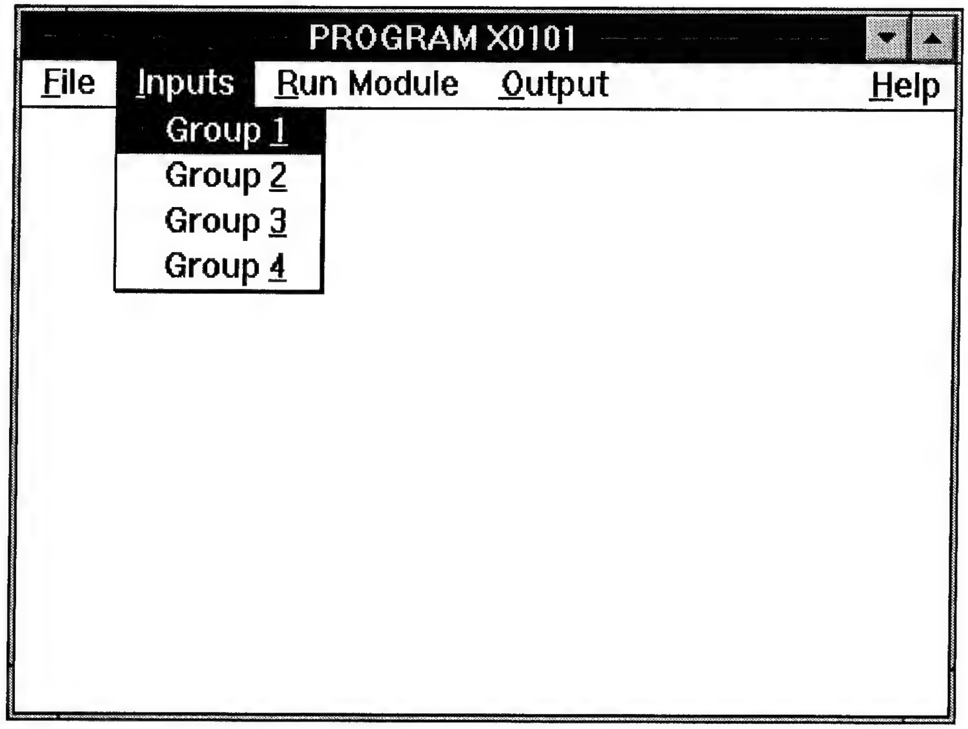


Figure 24. Beginning of graphic interface for data Group 1

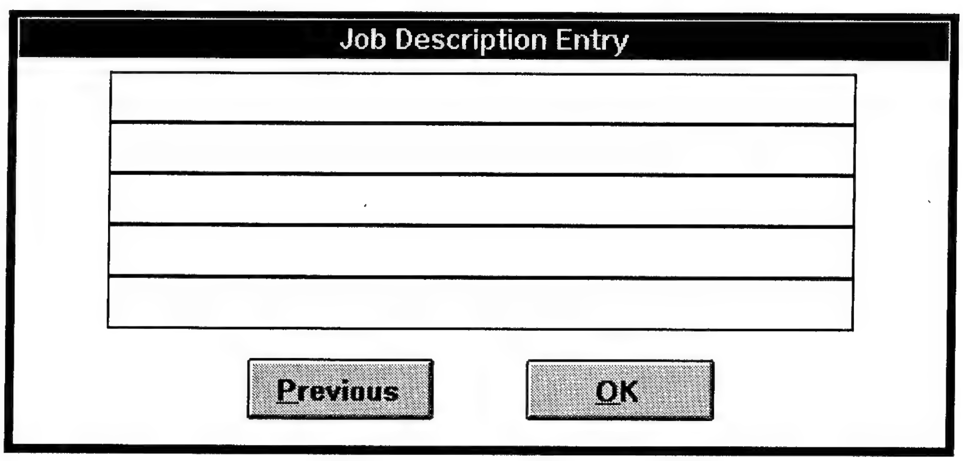


Figure 25. Job description input window

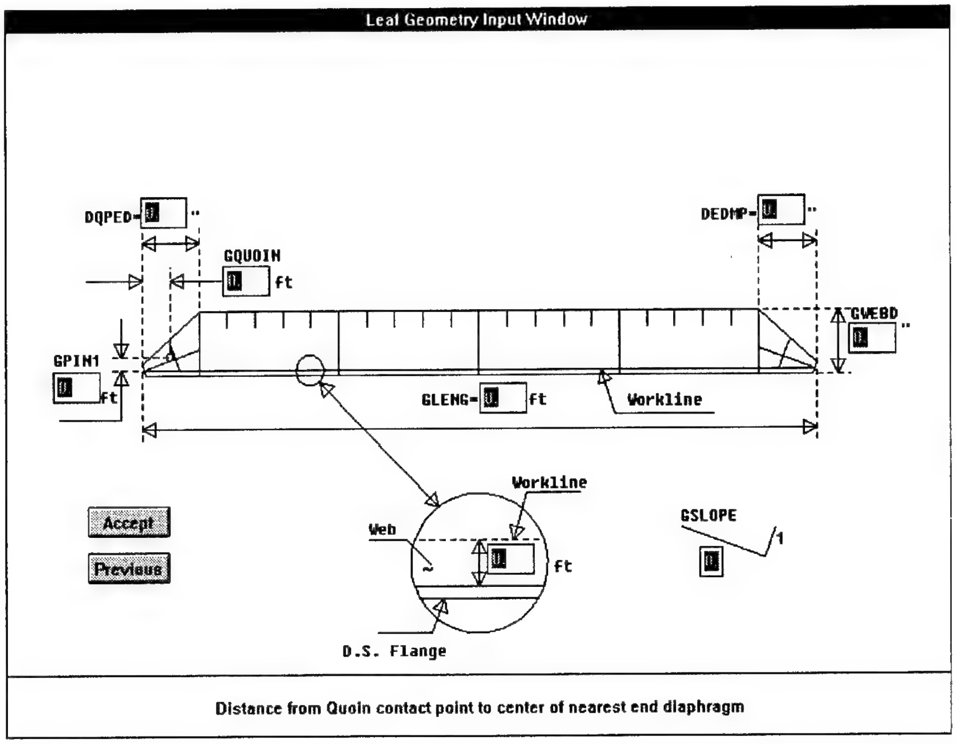


Figure 26. Leaf geometry input window

GLENG = length of leaf between contact points (ft).

GSLOPE = tangent of the angle between the gate leaf and the lock center line when the gate is in the fully mitered position.

GWORKL = offset from gate leaf working line to downstream edge of girder web (ft).

GQUOIN = distance along gate leaf working line from quoin contact point to gudgeon pin (ft).

GPIN1 = offset from center of gudgeon pin to gate working line (ft).

GWEBD = girder web depth or the clear distance between girder flanges. Assume a value for the first trial $\left(\frac{L}{15} \leq d \leq \frac{L}{8}\right)$ where L is the girder length (in.).

DQPED = distance from quoin contact point to center of a nearest end diaphragm, measured along the gate working line (in.).

DEDMP = distance from center of end diaphragm at miter end of gate to miter contact point, measured along gate working line (in.).

BGDFD = bottom girder downstream flange downward extension below the center line (usual value is 3 in.).

Pressures input window

The window in Figure 27 is provided to input the required water elevations. Elevations are in feet with respect to the same datum as ELSILL.

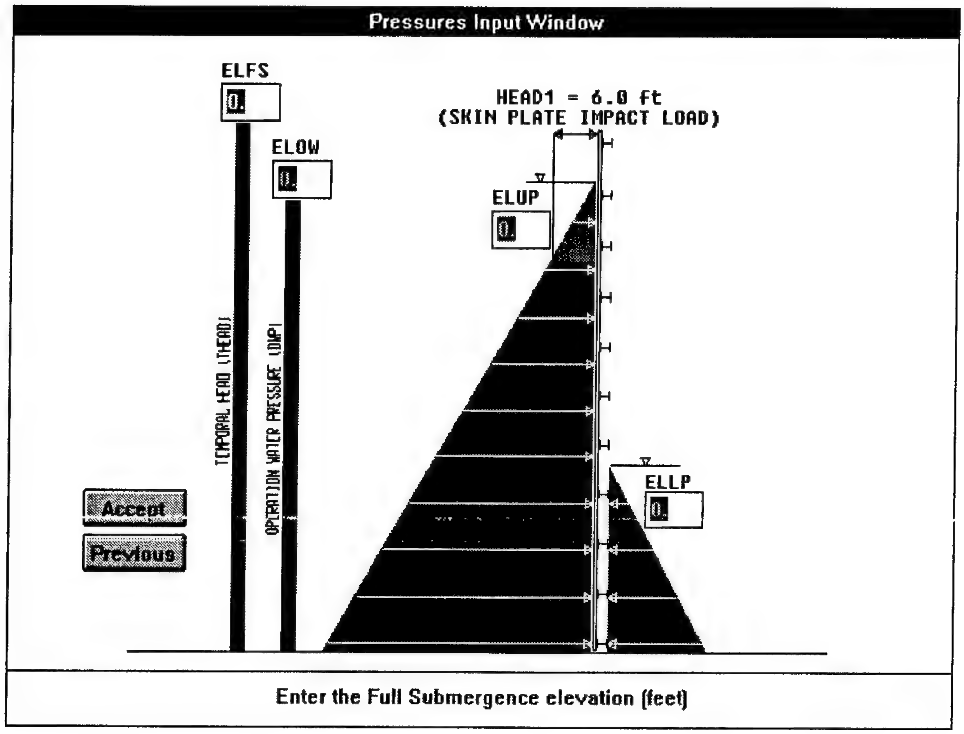


Figure 27. Pressures input window

ELUP = elevation of upper pool (ft).

ELLP = elevation of lower pool (ft).

ELFS = temporal head elevation (ft).

ELOW = operating water elevation (ft).

Number of girders input window

The window in Figure 28 is provided to input the total number of horizontal girders in the structure (NGIRDS). The user should assume a number to run RECDES module for the first time.

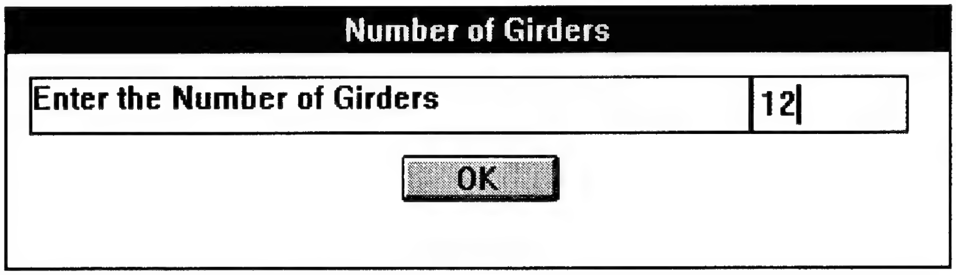


Figure 28. Number of girders input window (NGIRDS)

General geometry input window

The general geometry input window (Figure 29) is used to input the vertical distance of the girders to the sill.

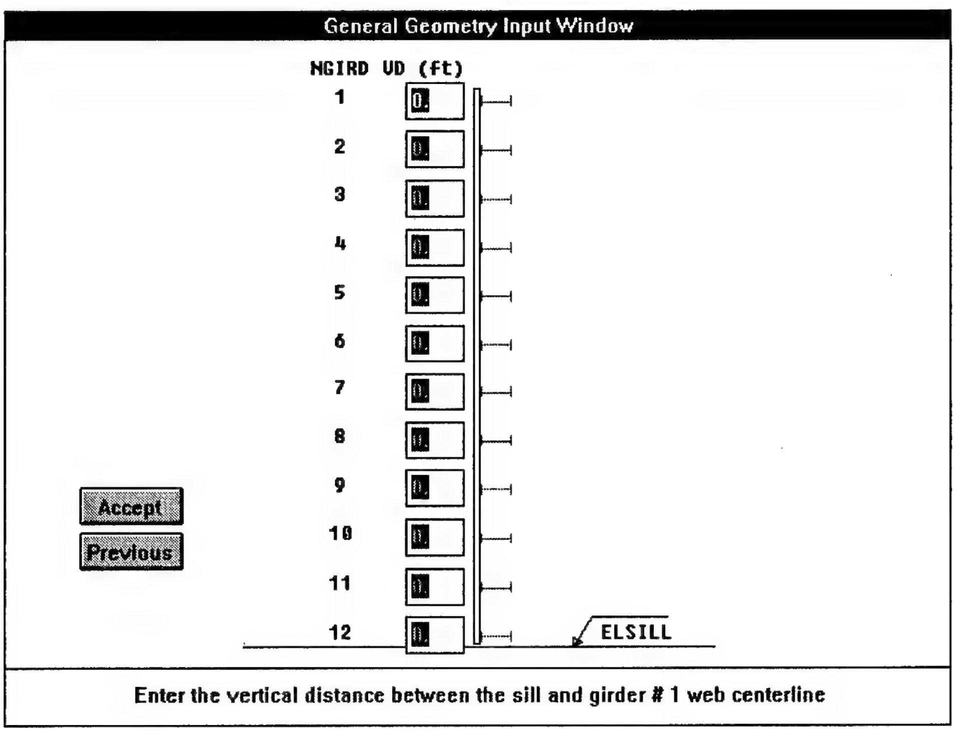


Figure 29. General geometry input window

NGIRD = girder number (one at top and NGIRDS at bottom of gate).

VD = vertical distance between the sill and the girder web center line (ft).

Gate leaf face input window

The gate leaf face input window (Figure 30) is used to input the overall vertical geometry and the required dead loads.

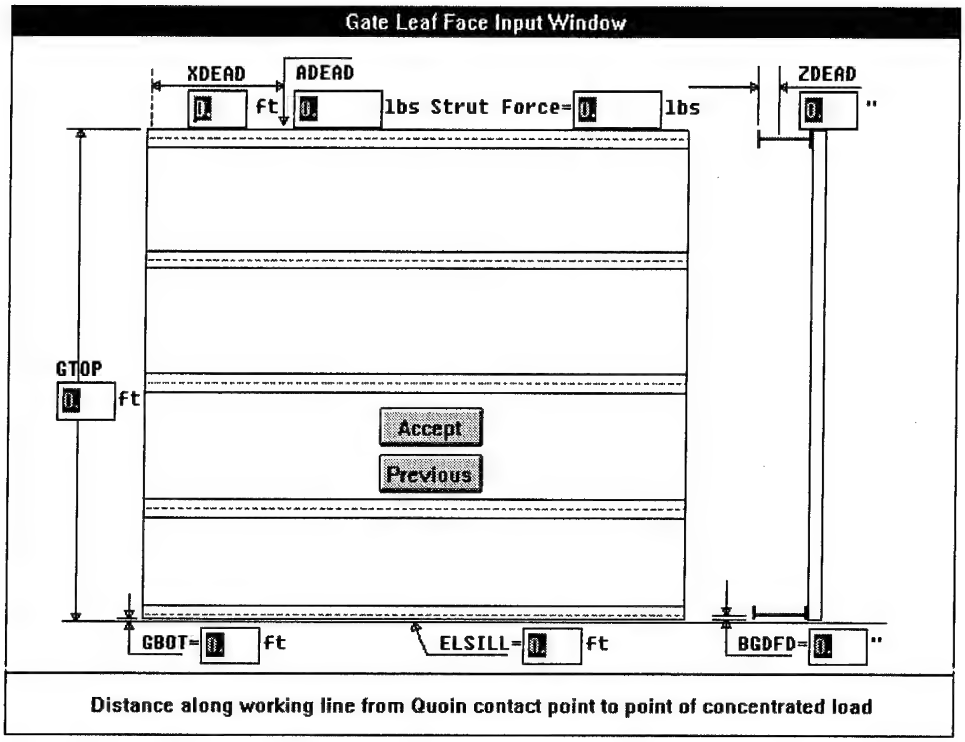


Figure 30. Gate leaf face input window

ELSILL = elevation of the sill with respect to a given datum (must be positive) (ft).

GBOT = distance from sill to bottom of skin plate (ft).

GTOP = distance from sill to overflow elevation at top of gate (ft).

ADEAD = additional loads, including mud and ice, bridgeway or walkway, intermediate diaphragm stiffeners, gusset plates, etc., pounds total force (gate weight should not be included here).

XDEAD = distance along gate working line from quoin contact point (x-coordinate) to centroid of ADEAD, ft (a value of zero will set it at the middle of GLENG).

ZDEAD = offset from downstream edge of girder web to centroid (z-coordinate) of ADEAD, in.

STRUTF = strut capacity force, lb, applied by strut arm in Load Case 5 (obstruction).

Panel group number input window

The panel group input window (Figure 31) is used to define the number of unique panel groups. A panel is the portion of the leaf between adjacent girders. Successive panels that have the same diaphragms spacing, intercostals arrangement, skin plate thickness, and girder spacing make up a panel group.

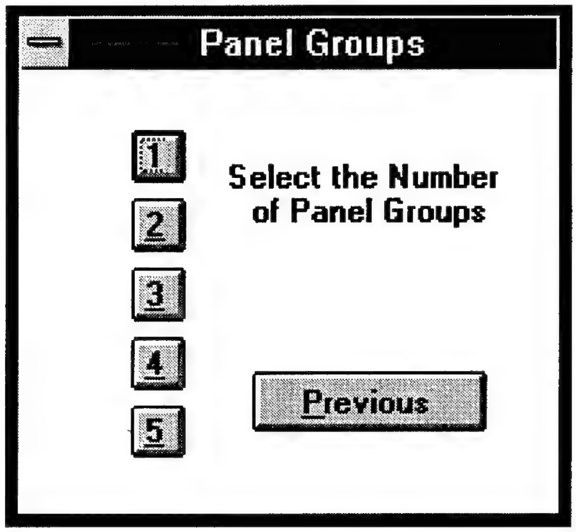


Figure 31. Panel group number input window

Panel group information

A panel group input window (Figure 32) is used to define the panel groups with the following input. A separate window will appear for each panel group.

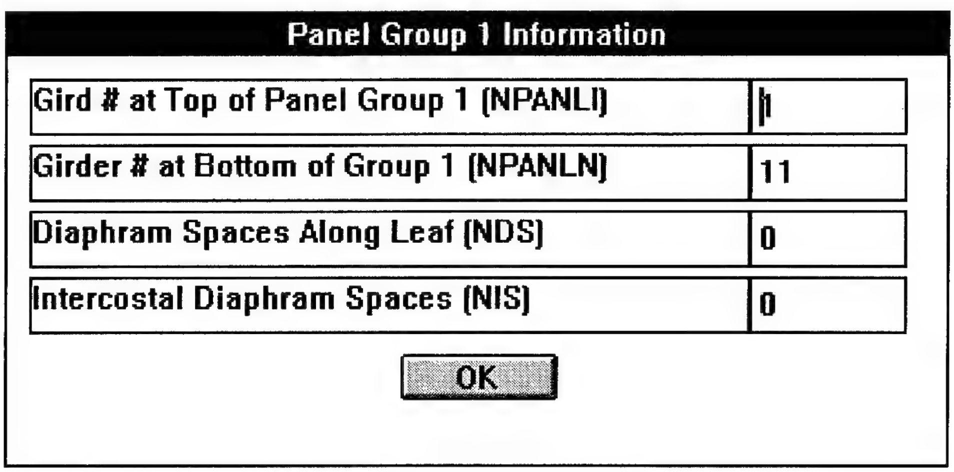


Figure 32. Panel group input window

NPANLI = girder number at top of panel group.

NPANLN = girder number at bottom of panel group.

NDS = number of diaphragm spaces between end diaphragms along the gate leaf.

NIS = number of intercostal spaces between adjacent diaphragms.

Load combinations input window

The window shown in Figure 33 is used to define the load combinations required to perform the design (see page 11 for details).

LC1, LC2, . . . , LC6 = load combination numbers.

LC3 = Equation 6 with I = 0.0 and ELLP = 0.

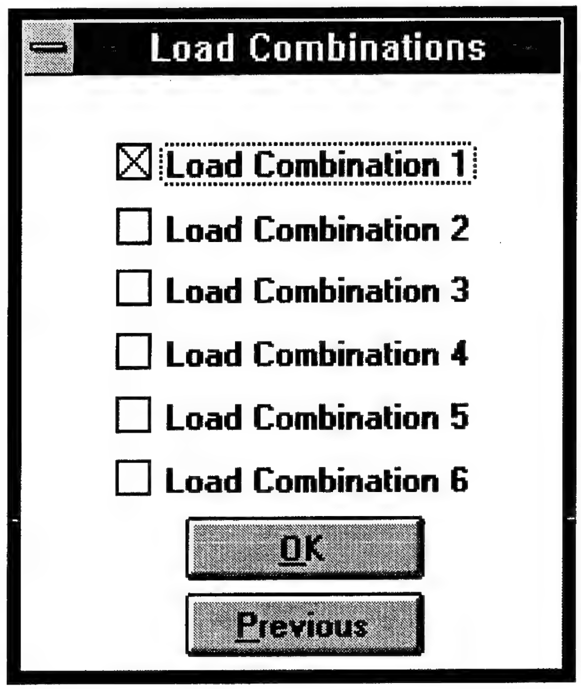


Figure 33. Load combination input window

Steel yield strengths input window

Values of yield stress are input in kips per square inch, using the steel yield strengths window (Figure 34).

FY = yield strength of all steel not specifically listed for one of the other items in the list.

FYW = yield strength of the steel in the girder webs.

FYF = yield strength of the steel in the girder flanges.

FYSK = yield strength of the steel in the skin plate.

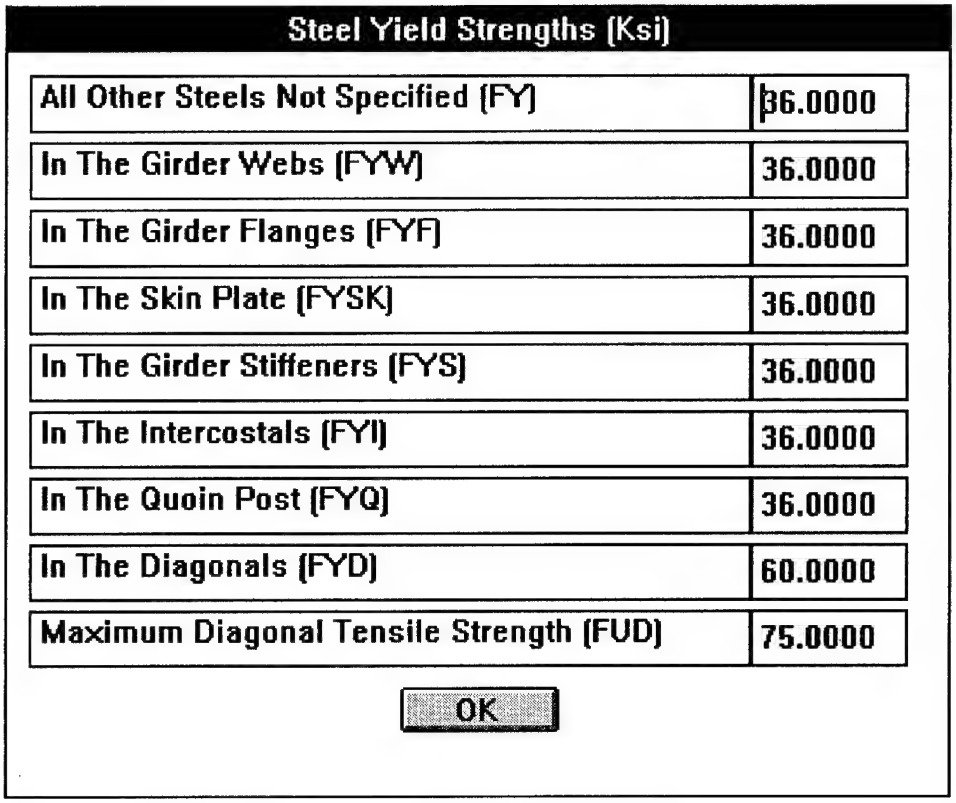


Figure 34. Steel yield strength input window

FYS = yield strength of the steel in the girder stiffeners.

FYI = yield strength of the steel in the intercostals.

FYQ = yield strength of the steel in the quoin post.

FYD = yield strength of the steel in the diagonals.

FU = maximum diagonal tensile strength.

Fatigue category values input window

Fatigue data are input using the fatigue category values input window (Figure 35). Fatigue values included in CMITERW-LRFD for load condition and fatigue categories are those specified in AISC-LRFD (1986).

LC = load condition of the gate.

CATSK = fatigue category of the skin plate.

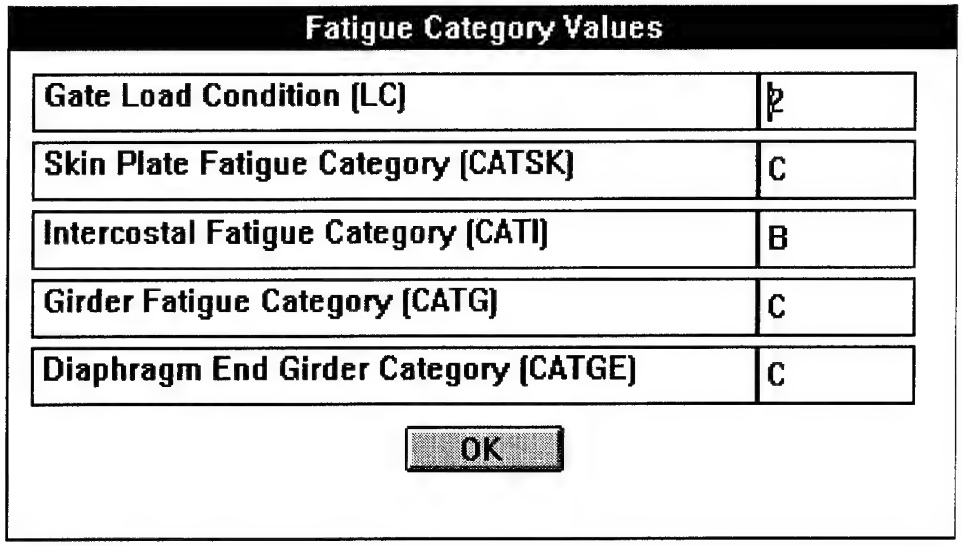


Figure 35. Fatigue category values input window

CATI = fatigue category of the intercostal.

CATG = fatigue category of the girders.

CATGE = fatigue category of the girders at end diaphragm.

Group 2

The data in Group 2 (Figure 36) provide detailed information on geometry and are required to run the INV module. The DES module must be run if the user wants to set the dimensions of the horizontal girders and intercostals. Table 2 shows all the possible combinations where Group 2 can be used. Following is the sequence to generate data Group 2 using the graphic interface.

To start the graphic interface for data Group 2, the user should select the **Group 2** from the **Input** option (Figure 37). The following windows will appear for data input.

Group number input window (web thickness)

In the first window following Group 2 selection (Figure 38), enter the number of different girder web thicknesses. Zero or one means that all the girders have the same web thickness. If a number greater than one is specified, the windows of Figures 39 and 40 will appear the number of times specified above. Otherwise, only the window shown by Figure 40 will come up.

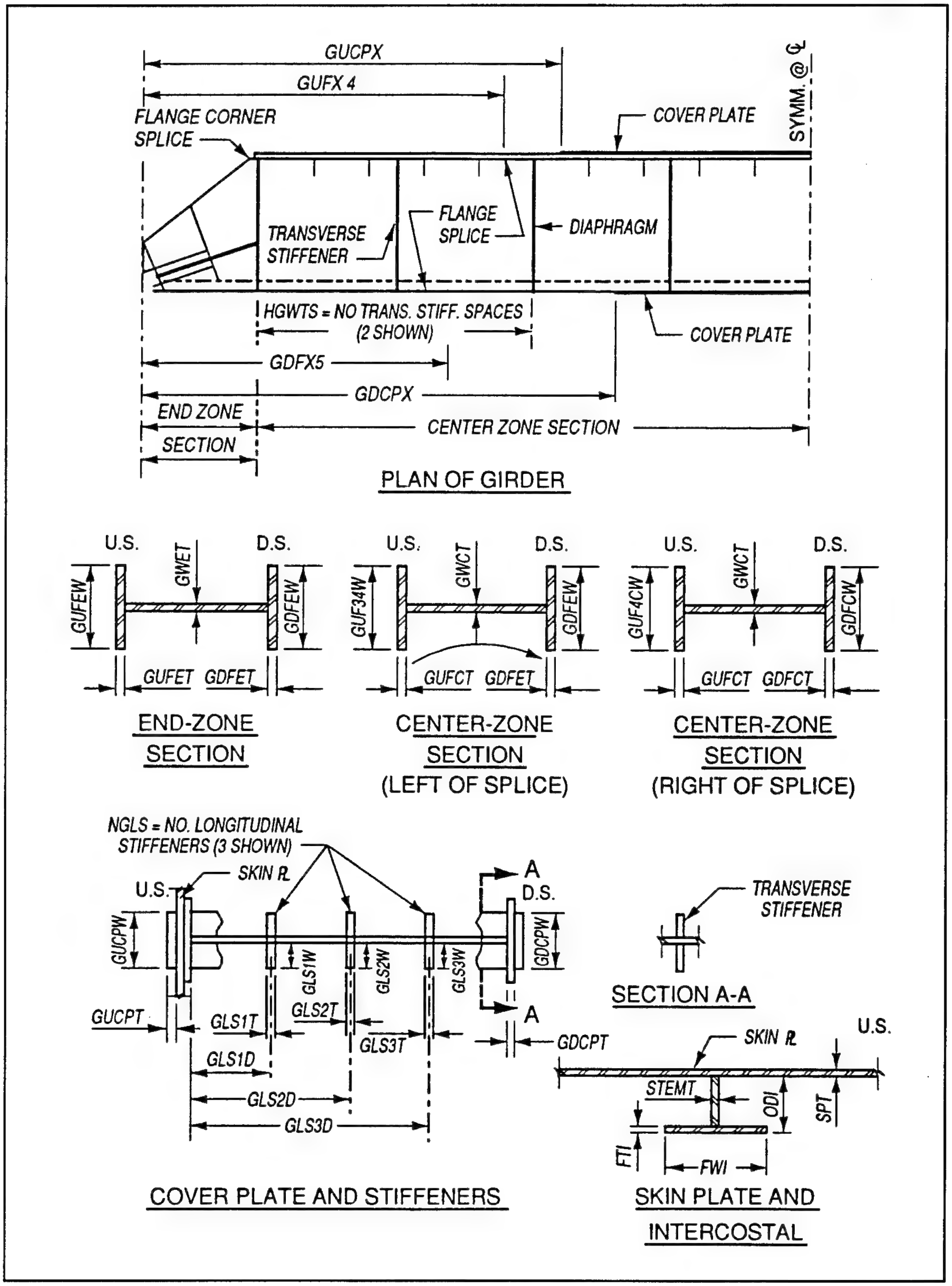


Figure 36. Data items, Group 2

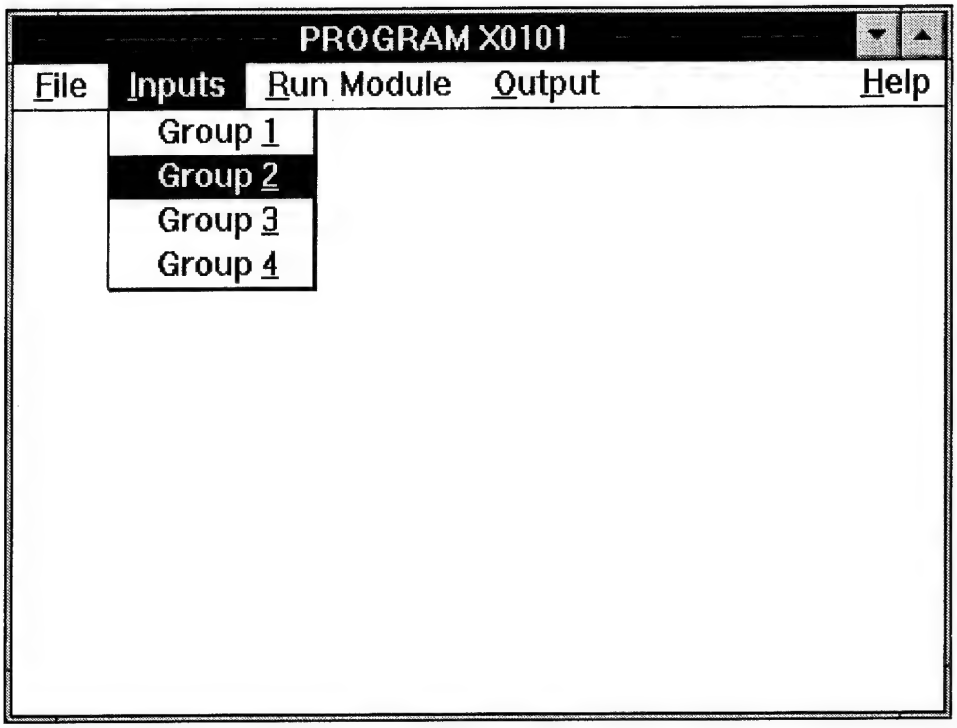


Figure 37. Beginning of graphic interface for data Group 2

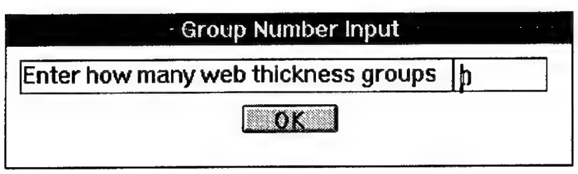


Figure 38. Group number input window

Web thickness groups input window

NGIRDI = girder number at top of group of girders (upper girder).

NGIRDN = girder number at bottom of group of girders (lower girder).

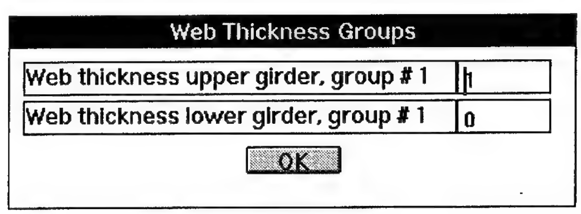


Figure 39. Web thickness groups input window

If the number of groups is zero or one, NGIRDI will be equal to one and NGIRDN will be equal to the total number of girders (NGIRDS). The program will skip this window, moving to the web thickness input window. However, this window will appear the number of times specified for the web thickness group if the number is more than one.

Web thickness input window

The web thickness input window (Figure 40) is used to input the girder web thicknesses. The minimum thickness for design is established by TMGW (Group 4). Values are in inches. This window will appear the number of times specified on the group number window for web thickness. Group 4 shows the default minimum values.

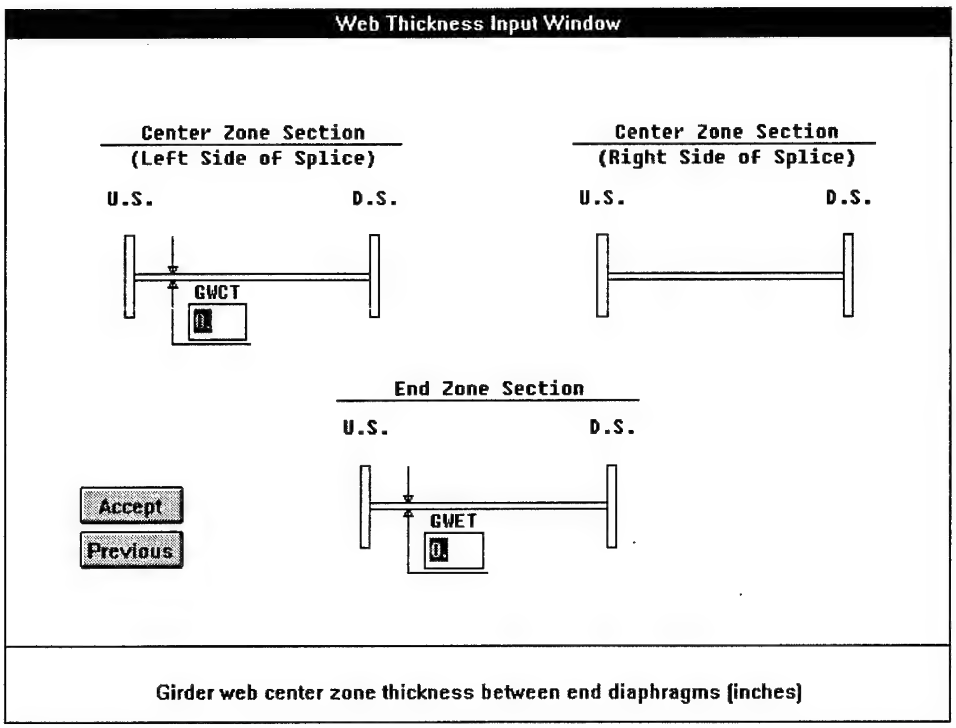


Figure 40. Web thickness input window

GWET = girder web end zone thickness in quoin post area.

GWCT = girder web center zone thickness between end diaphragms.

Group number input window (upstream flanges)

For the window in Figure 41, enter the number of girders with different upstream flange sizes. Zero or one means that all the girders have the girder flanges of the same size. If a number greater than one is specified, a window similar to Figure 40 will appear the number of times specified above, otherwise Figure 42 will appear.

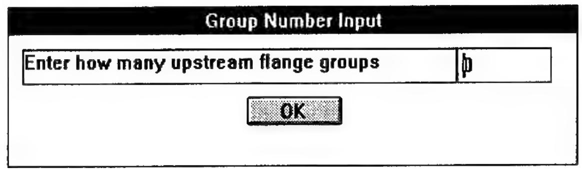


Figure 41. Upstream flange group input window

Upstream flange input window

The window in Figure 42 is used to specify the sizes of the upstream girder flanges. The minimum thicknesses for design are established by TMGW (Group 4). Values are in inches.

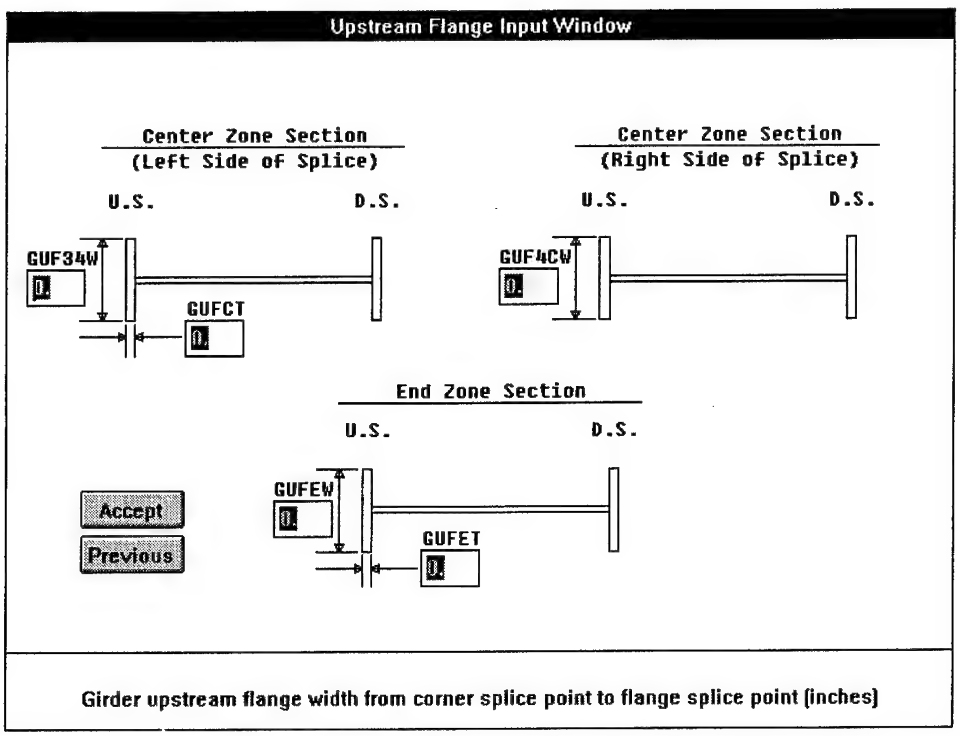


Figure 42. Upstream flange input window

GUFEW = girder upstream flange end zone width from girder end to corner splice.

GUFET = girder upstream flange end zone thickness from girder end to corner splice.

GUF34W = girder upstream flange width from corner splice point to flange splice point.

GUF4CW = girder upstream flange width from flange splice point to girder center line.

GUFCT = girder upstream flange thickness from corner splice point, through flange splice point, to girder center line, and thickness of intermediate diaphragm upstream flange.

Upstream cover plate data input window

The window in Figure 43 is used to input the upstream cover plate information. Values are in inches. If no cover plate is needed, the user should press **Accept** to use the default values (zero).

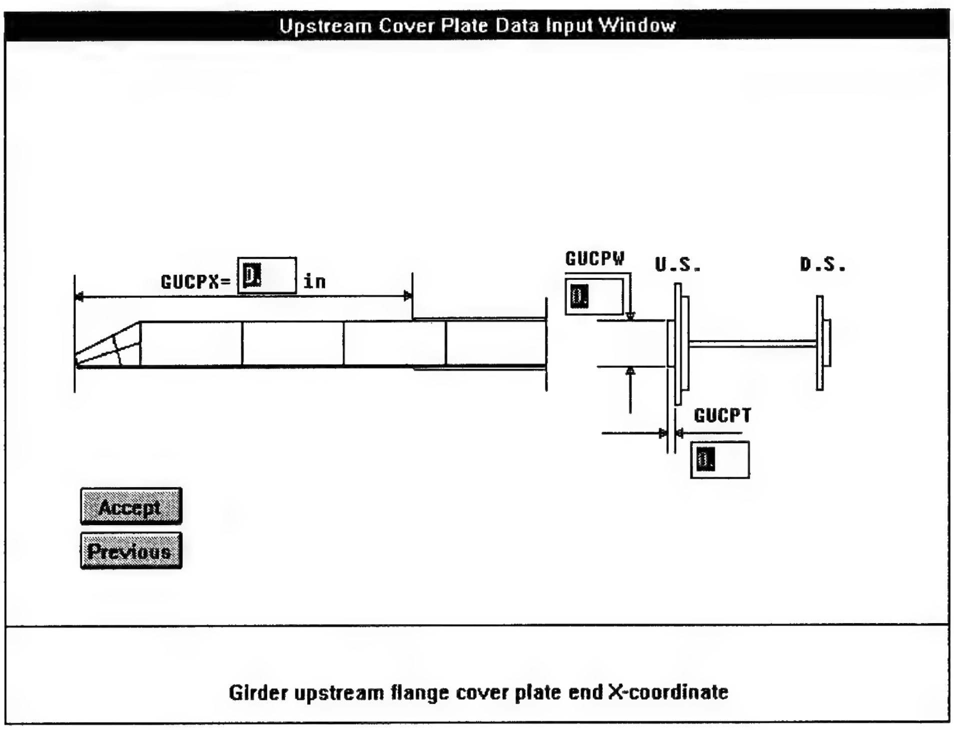


Figure 43. Upstream cover plate input window

GUCPX = girder upstream cover plate end x-coordinate.

GUCPW = girder upstream cover plate width.

GUCPT = girder upstream cover plate thickness.

Group number input window (downstream flanges)

For the window in Figure 44, enter the number of different downstream flange sizes. Zero or one means that all the girders have the same size. If a number greater than one is specified, a window similar to Figure 40 will appear the number of times specified above. Otherwise, the following figure will appear.

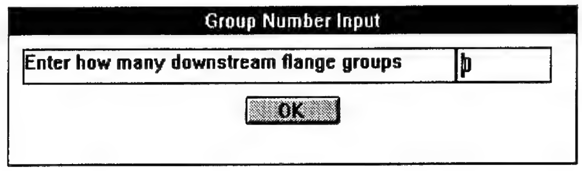


Figure 44. Downstream flange group input window

Downstream flange input window

The window in Figure 45 is used to specify the downstream girder flanges. The minimum thicknesses for design are established by TMGW (Group 4). Values are in inches.

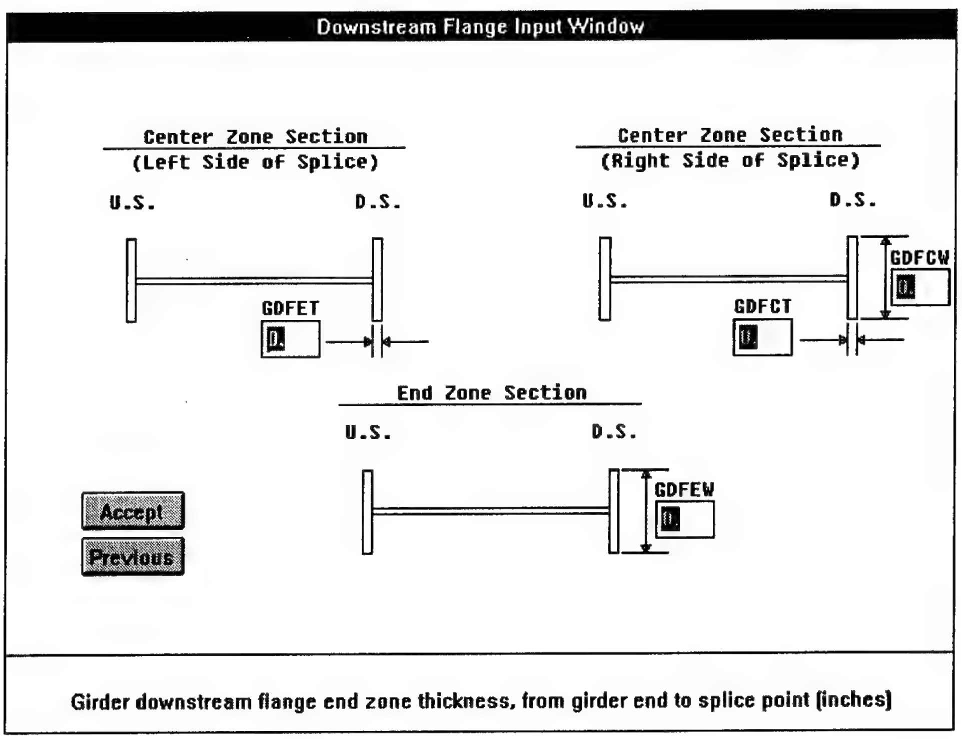


Figure 45. Downstream flange input window

GDFEW = girder downstream flange end zone width from girder end to splice point.

GDFET = girder downstream flange end zone thickness from girder end to splice point.

GDFCW = girder downstream flange center zone width from splice point to girder center line.

GDFCT = girder downstream flange center zone thickness from splice point to girder center line.

Downstream cover plate data input window

The downstream cover plate data input window is used to define the downstream cover plate dimensions. All values are in inches. If no cover plate is needed, the user should press **Accept** to continue with the default values (zero).

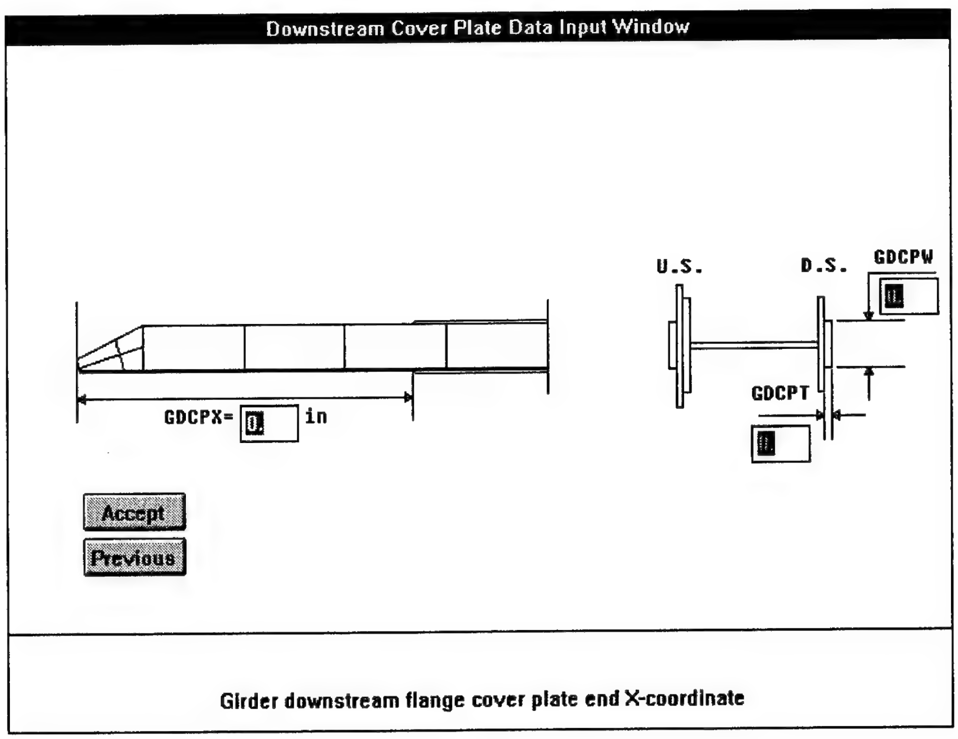


Figure 46. Downstream cover plate data input window

GDCPX = girder downstream flange cover plate end x-coordinate.

GDCPW = girder downstream cover plate width.

GDCPT = girder downstream cover plate thickness.

Group number input window (splice points)

For window in Figure 47, enter the number of girders with different flange splice configurations. Zero or one means that all the girders have the same splice points. If a number greater than one is specified, a window similar to Figure 40 will appear the number of times specified above; otherwise, Figure 48 will appear.

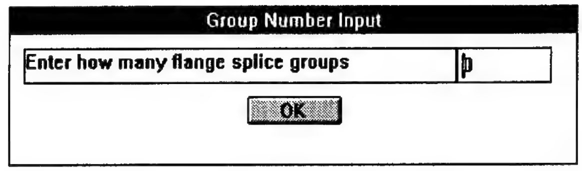


Figure 47. Splice points groups input window

Flange splice points input window

The window in Figure 48 is used to specify the positions of flange splice points. Dimensions are in inches.

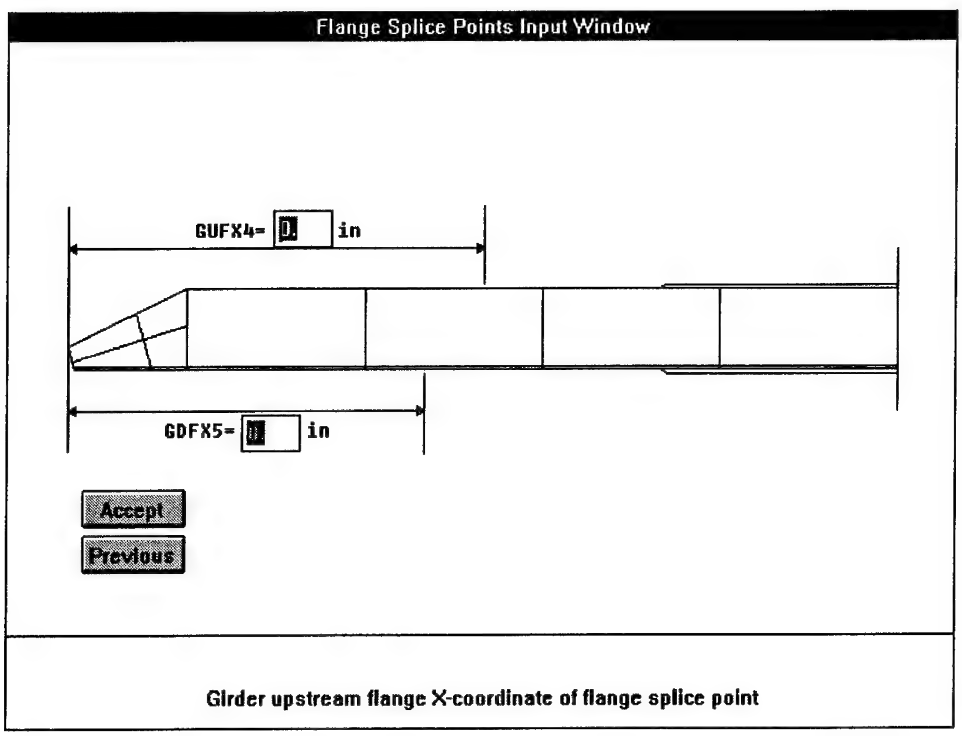


Figure 48. Flange splice points input window

GUFX4 = girder upstream flange x-coordinate of flange splice point.

GDFX5 = girder downstream flange x-coordinate of flange splice point.

Group number input window (web stiffeners)

For window in Figure 49, enter the number of unique configurations for web transverse and longitudinal stiffeners. Zero or one means that all the girders have the same configuration of transverse and longitudinal stiffeners. If a number greater than one is specified, a window similar to Figure 40 will appear the number of times specified above; otherwise, the windows of Figures 50, 51, and 52 will appear.

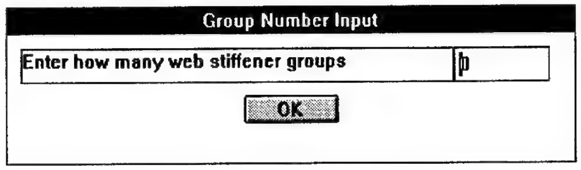


Figure 49. Web stiffener group number input window

Transverse stiffeners input window

The number of transverse stiffeners input window is used to specify the number of transverse stiffener spaces between diaphragms.

NGWTS = number of girder web transverse stiffener spaces between adjacent intermediate diaphragms. Use zero if there are no stiffeners.

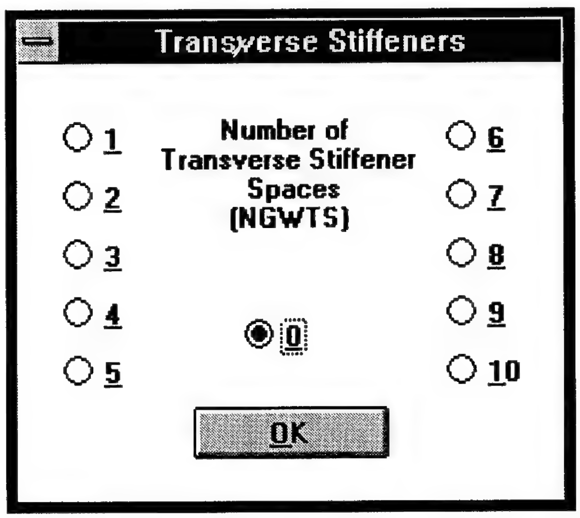


Figure 50. Number of transverse stiffeners input window

Longitudinal stiffeners input window

The window in Figure 51 is used to define the number of longitudinal stiffeners on the girder web.

NGLS = number of girder longitudinal stiffener pairs to be used. If more than one pair is used, Pair 1 will be upstream of Pair 2 and Pair 2 will be upstream of Pair 3.

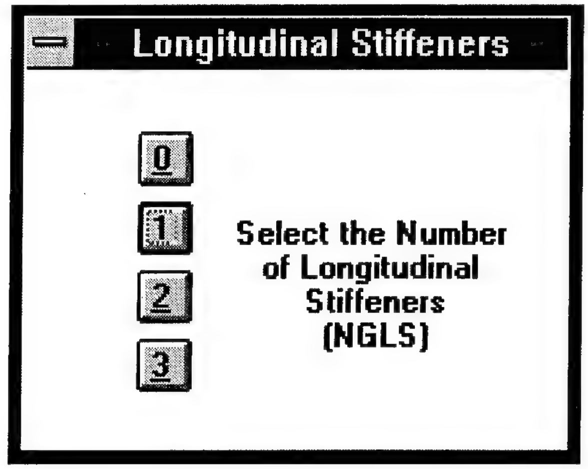


Figure 51. Number of longitudinal stiffeners input window

Longitudinal web stiffeners data input window

The longitudinal stiffeners input window (Figure 52) is used to input the locations and dimensions of the longitudinal stiffeners. Dimensions are in inches.

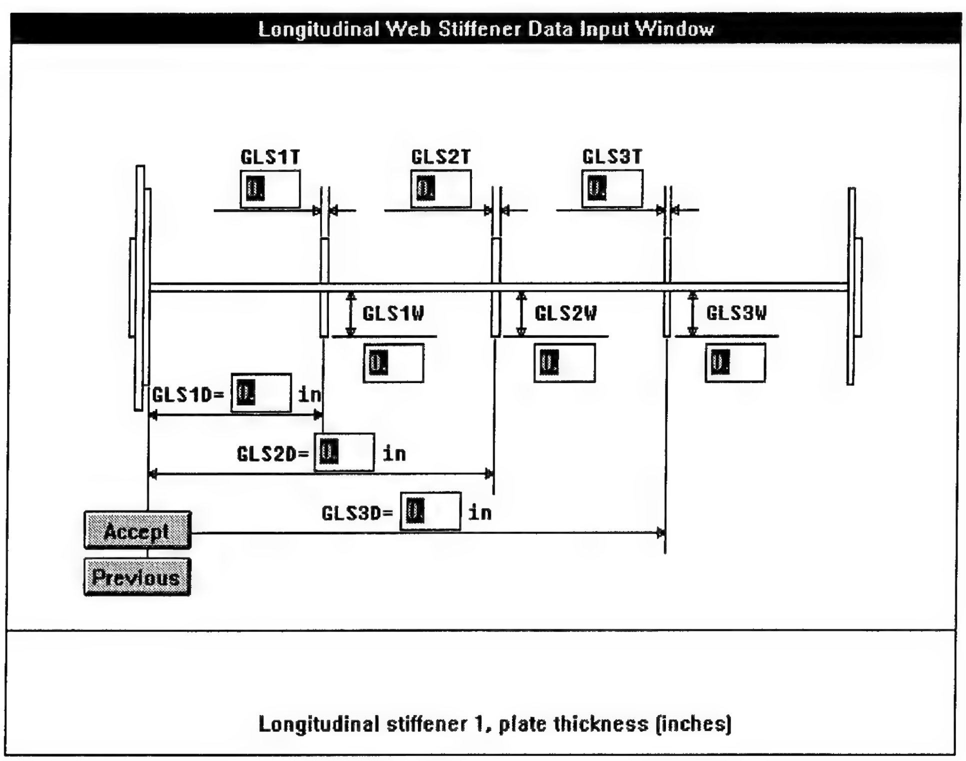


Figure 52. Longitudinal stiffeners input window

GLS1D = girder longitudinal Stiffener 1, distance from upstream edge of web to center of stiffener plate.

GLS1W = girder longitudinal Stiffener 1, width of each plate in the pair. Use negative value if stiffeners are on only one side of web.

GLS1T = girder longitudinal Stiffener 1, thickness of each plate.

GLS2D = girder longitudinal Stiffener 2, distance from upstream edge of web to center of stiffener plate in Pair 2. Must be greater than GLS1D. Use zero if NGLS is less than two.

GLS2W = girder longitudinal Stiffener 2, width of each plate in the pair. Use negative value if stiffeners are on only one side of web. Use zero if NGLS is less than two.

GLS2T = girder longitudinal Stiffener 2, thickness of each plate. Use zero if NGLS is less than two.

GLS3D = girder longitudinal Stiffener 3, distance from upstream edge of web to center of stiffener plate in Pair 2. Must be greater than GLS2D. Use zero if NGLS is less than three.

GLS3W = girder longitudinal Stiffener 3, width of each plate in the pair. Use negative value if stiffeners are on only one side of web. Use zero if NGLS is less than three.

GLS3T = girder longitudinal Stiffener 3, thickness of each plate. Use zero if NGLS is less than three.

Number input window (intercostal/skin plate)

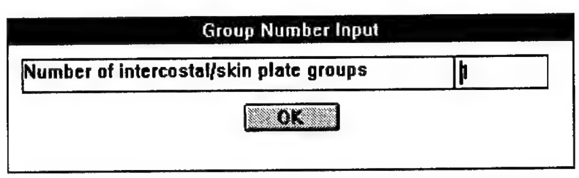


Figure 53. Intercostal/skin plate groups input window

For the window in Figure 53, enter the number of intercostal/skin plate groups. Zero or one means that all the panels have the same intercostal size and skin plate thickness. If a number greater than one is specified, a window similar to Figure 40 will appear the number of times specified above; otherwise, the following figure will appear.

Intercostal and skin plate data input window

The intercostal/skin plate input window defines the intercostal size and skin plate thickness for both investigation and design.

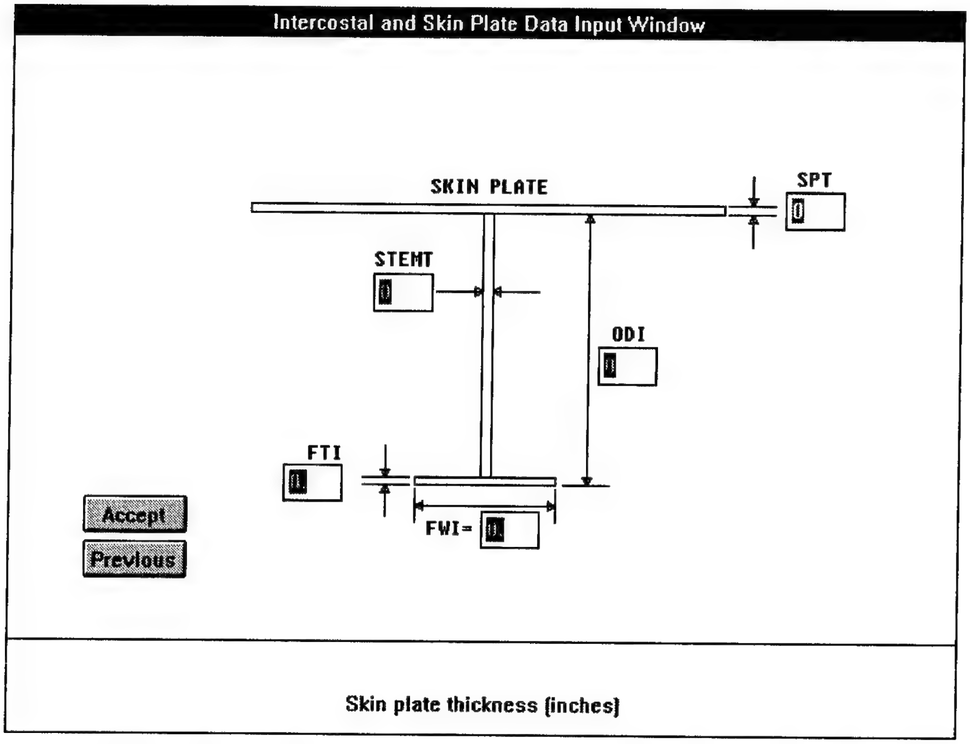


Figure 54. Intercostal/skin plate input window

SPT = skin plate thickness. The minimum thickness for design is established by TMSP in data Group 4. All values are in inches.

ODI = overall depth of intercostal stem, including FTI, perpendicular to skin plate.

STEMT = thickness of intercostal stem.

FWI = flange width of intercostal (T-section).

FTI = flange thickness of intercostal (T-section).

Group 3

The data in Group 3 are required to run the DES module if the design of the following detailed elements is desired: end diaphragms, quoin post, thrust diaphragm, tapered end section, and diagonals (Figures 55 and 56). Following is

the sequence to generate data Group 3 using the graphic interface. Table 2 shows all the possible combinations where Group 3 can be used. Figures 58 through 61 show the input windows required to define geometry for the end diaphragms, quoin post, thrust diaphragm, tapered end section, and diagonals. Following each figure is an explanation of the input data.

To start the graphic interface for data Group 3, the user should select **Group 3** from the **Input** option (Figure 57).

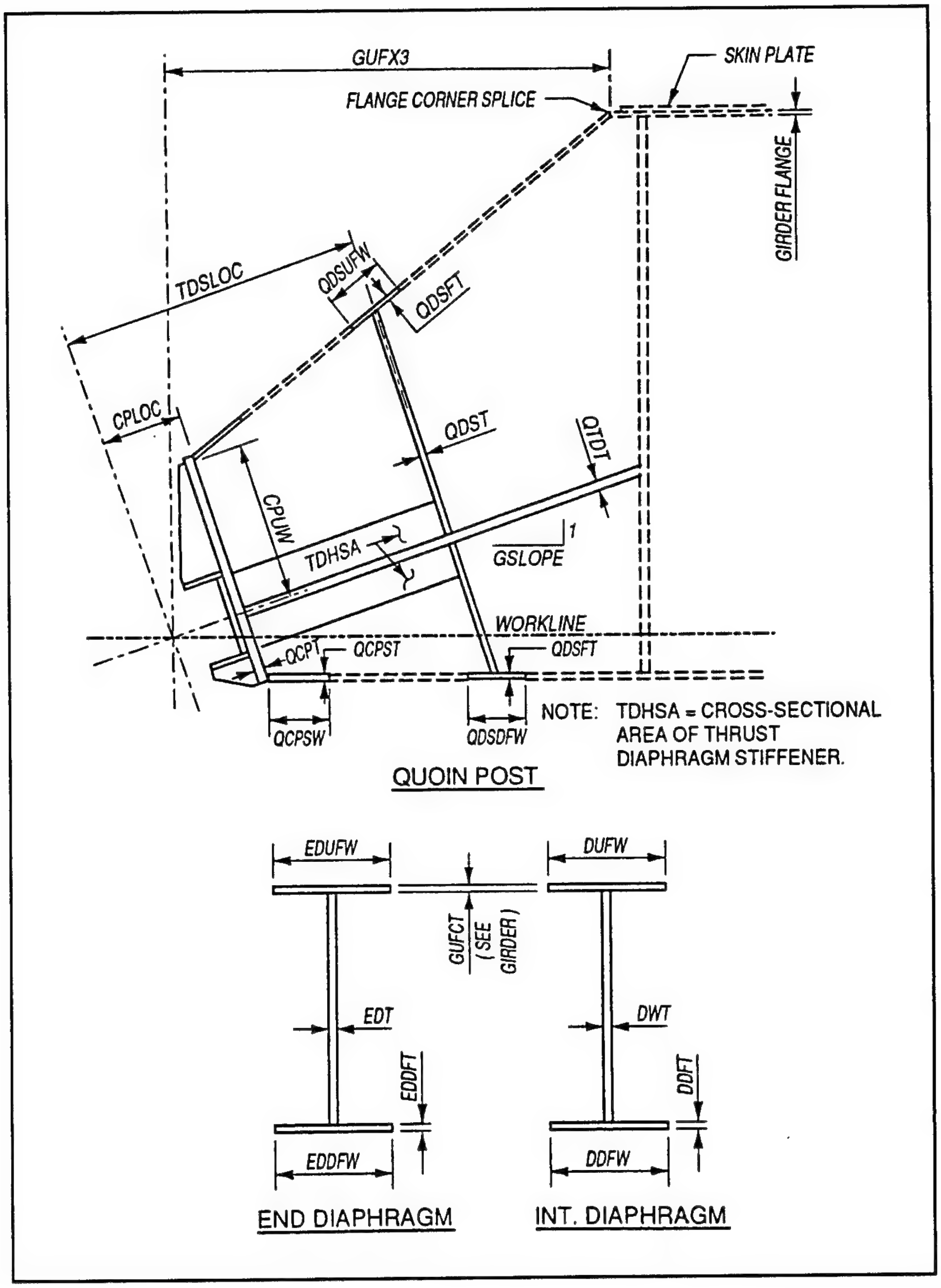


Figure 55. Group 3, quoin, tapered end, and end diaphragm data

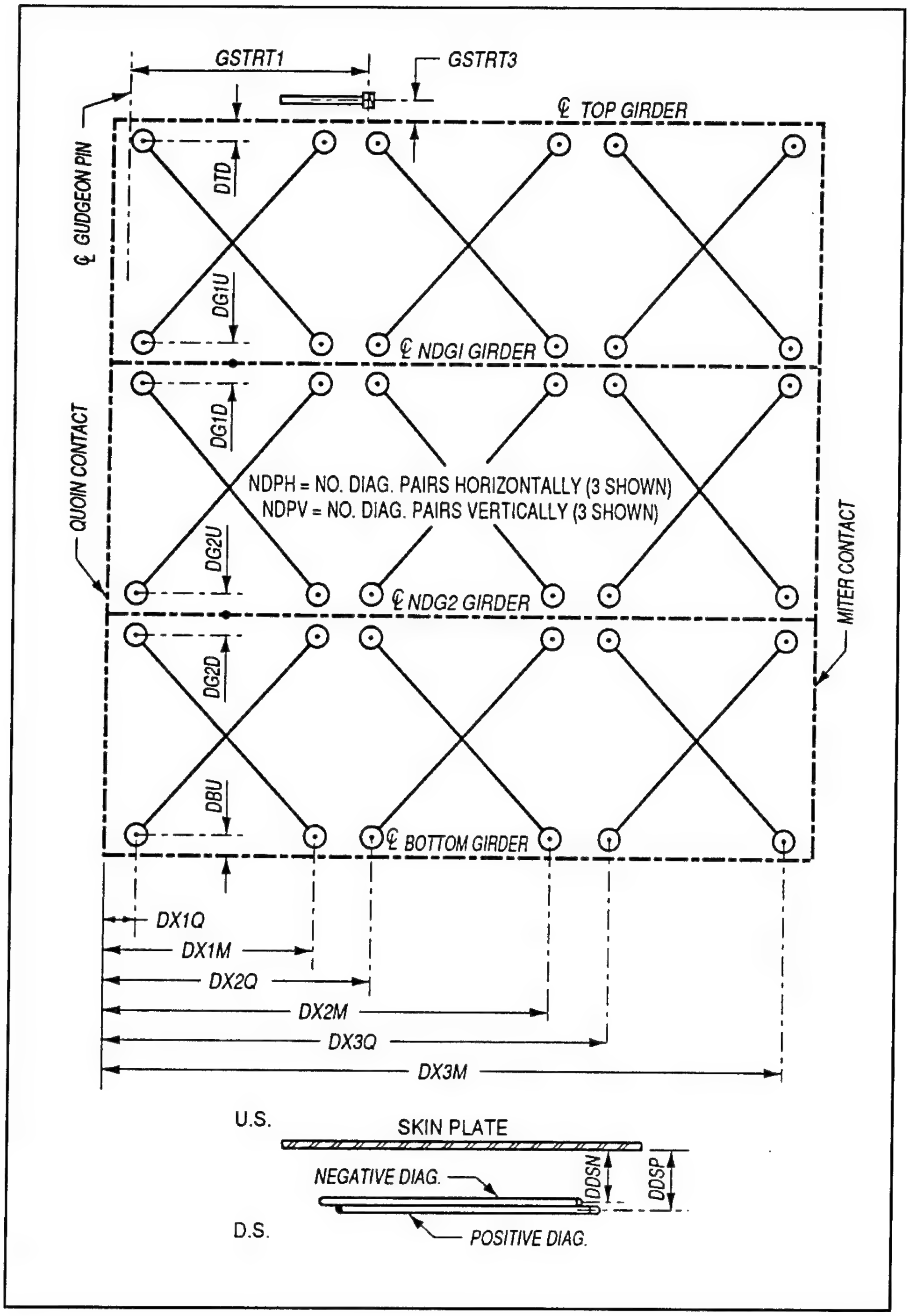


Figure 56. Group 3, diagonals

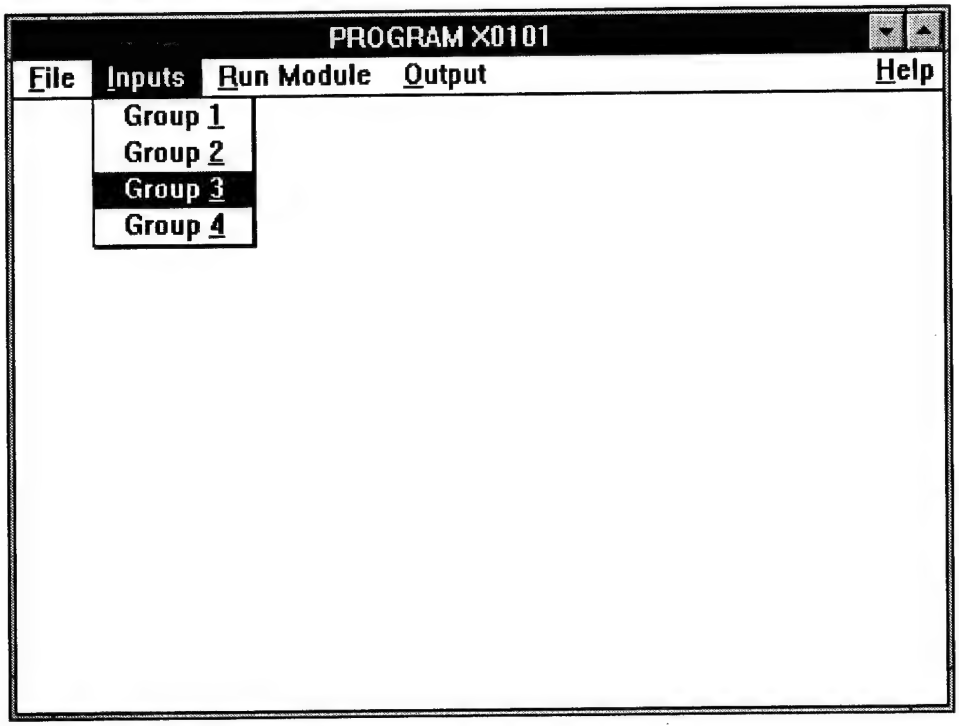


Figure 57. Beginning of graphics interface for Group 3

Required strut geometry

GSTRT1 = distance along gate working line from gudgeon pin to strut pin at top girder (ft) (Figure 56).

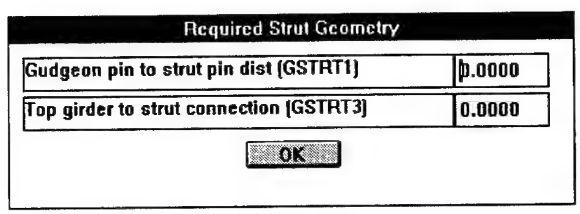


Figure 58. Strut geometry input window

GSTRT3 = vertical distance from center line of top girder up to strut connection point (ft) (Figure 56).

Diaphragm data input window

EDT = end diaphragm web thickness. For design purposes, use a value of zero (in.) (Figure 55).

EDUFW = end diaphragm upstream flange width (in.) (Figure 55).

EDDFW = end diaphragm downstream flange width (in.) (Figure 55).

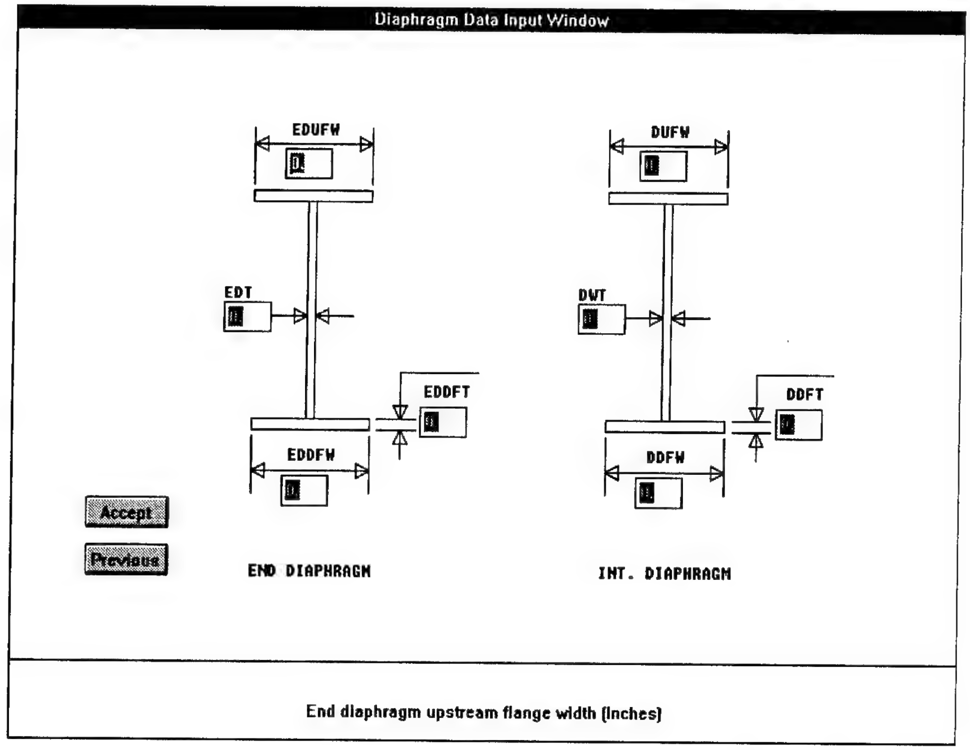


Figure 59. Diaphragm data input window

EDDFT = end diaphragm downstream flange thickness. Upstream flange thickness is GUFCT in data list GFU (Group 2) (in.) (Figure 55).

DUFW = diaphragm upstream flange width (in.) (Figure 55).

DDFW = diaphragm downstream flange width (in.) (Figure 55).

DDFT = diaphragm downstream flange thickness (in.). (The upstream flange thickness is set by GUFCT in data list GFU (Group 2) (Figure 55)).

DWT = diaphragm web thickness (in.) (Figure 55).

Required quoin post data input window

GUFX3 = girder upstream flange x-coordinate of corner splice point (in.) (Figure 55).

TDSLOC = thrust diaphragm stiffener plate location, distance along thrust diaphragm from quoin contact point to center of thrust diaphragm stiffener plate (in.) (Figure 55).

CPLOC = distance along line of thrust diaphragm from quoin contact point to the inside edge of the end plate (in.) (Figure 55).

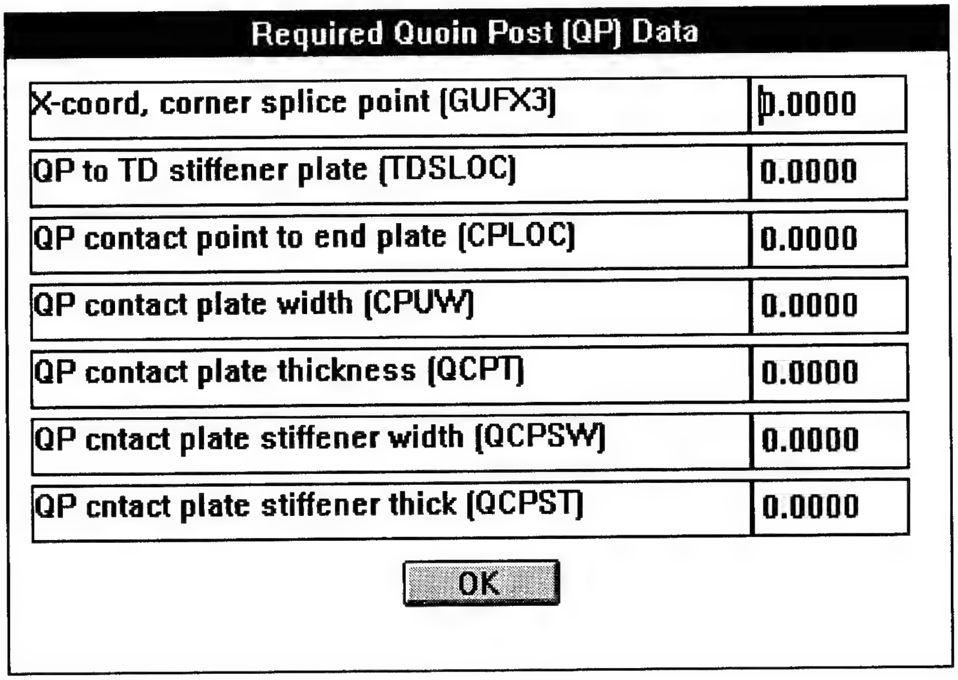


Figure 60. Quoin post input window

CPUW = quoin post contact plate width from center line of the thrust diaphragm to upstream corner of the end plate. The downstream partial width is calculated by the program (in.) (Figure 55).

QCPT = quoin post contact plate thickness (in.) (Figure 55).

QCPSW = quoin post contact plate stiffener width (in.) (Figure 55).

QCPST = quoin post contact plate stiffener thickness (in.) (Figure 55).

Required thrust diaphragm data input window

QTDT = quoin post thrust diaphragm thickness. A value of zero will cause the QTDT to be selected by the program (in.) (Figure 55).

QDST = quoin post thrust diaphragm stiffener plate thickness (in.) (Figure 55).

QDSUFW = quoin post thrust diaphragm stiffener plate upstream flange width. Use a value of zero to omit the upstream half of the stiffener plate and its flange (in.) (Figure 55).

QDSDFW = quoin post thrust diaphragm stiffener plate downstream flange width. Use a value of zero to omit the downstream half of the stiffener plate and its flange (in.) (Figure 55).

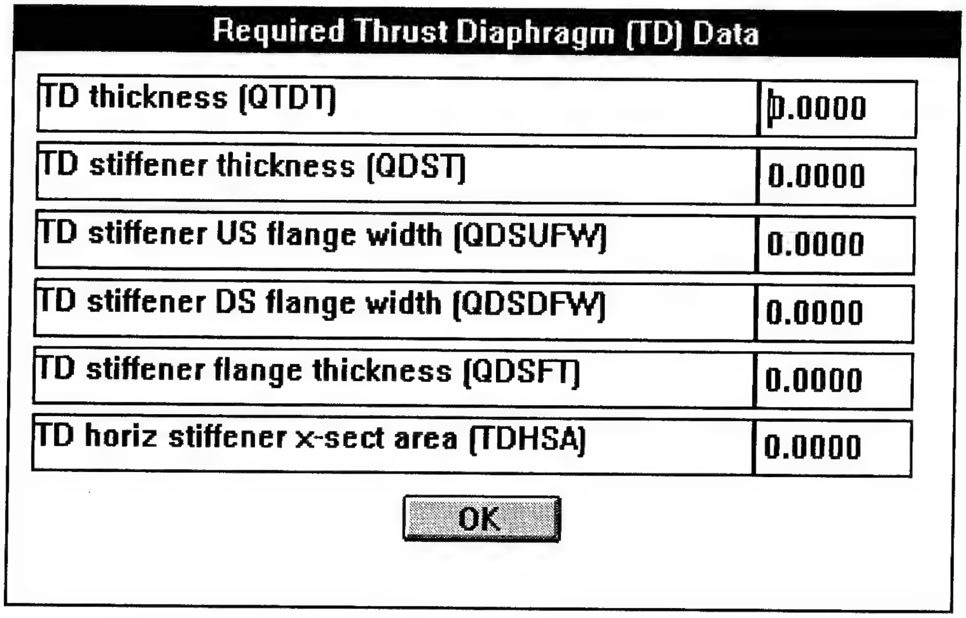


Figure 61. Thrust diaphragm input window

QDSFT = quoin post thrust diaphragm stiffener plate flange thickness (in.) (Figure 55).

TDHSA = thrust diaphragm horizontal stiffener cross-section area, square inches. This stiffener is horizontal, extending from the contact plate to the end diaphragm, located halfway up in the space between girder webs. Use a value of zero to omit this plate (in^2.).

Horizontal diagonal pairs input window

NDPH = number of diagonal pairs, horizontally (three maximum) (Figure 56).

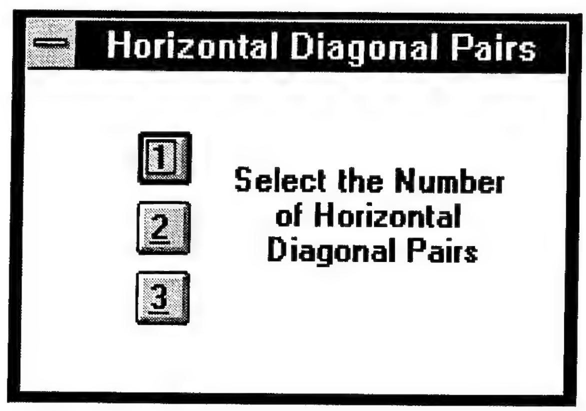


Figure 62. Horizontal diagonal pairs input window

Required diagonal geometry input window

The horizontal diagonal input window (Figure 63) describes the x-coordinates along the gate working line from the quoin contact point to the ends of diagonals and the eccentricities normal to the skin plate (Figure 56). All x-coordinates are in inches. The window in Figure 63 assumes that three horizontal pairs were selected in the horizontal diagonal pair input window (Figure 62).

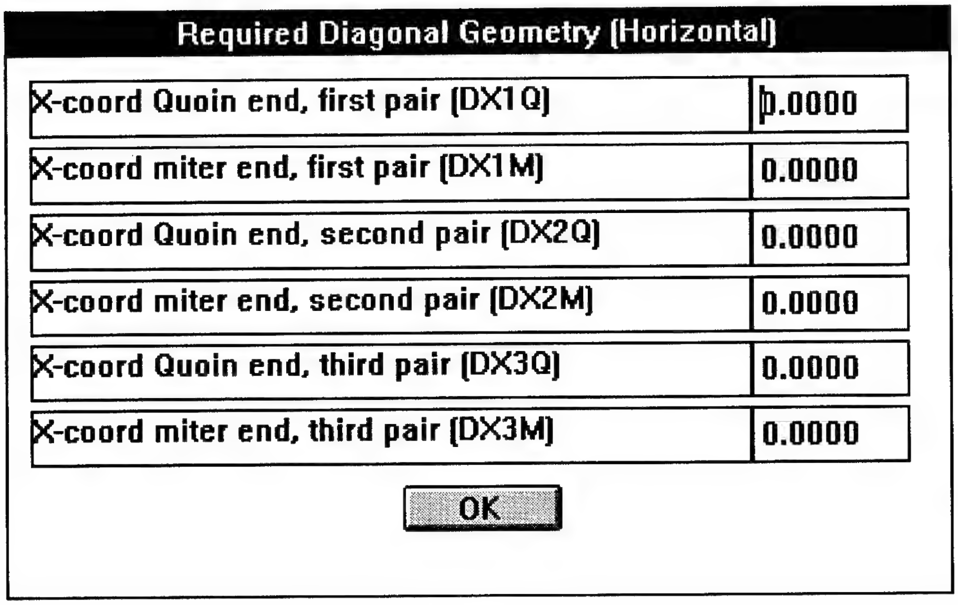


Figure 63. Horizontal diagonal input window

DX1Q = x-coordinate of diagonal pair end toward the quoin, first pair.

DX1M = x-coordinate of diagonal pair end toward the miter end, first pair.

DX2Q = x-coordinate of diagonal pair end toward the quoin, second pair.

DX2M = x-coordinate of diagonal pair end toward the miter end, second pair.

DX3Q = x-coordinate of diagonal pair end toward the quoin, third pair.

DX3M = x-coordinate of diagonal pair end toward the miter end, third pair.

Vertical diagonal pairs

NDPV = number of diagonal pairs vertically (Figure 56).

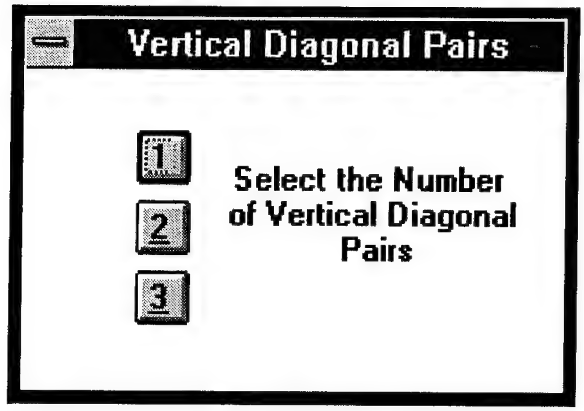


Figure 64. Vertical diagonal pairs input window

Required diagonal geometry (vertical) input window

The window in Figure 65 describes the vertical relationship between the diagonal ends and the gate vertical geometry (Figure 56). Values are in inches.

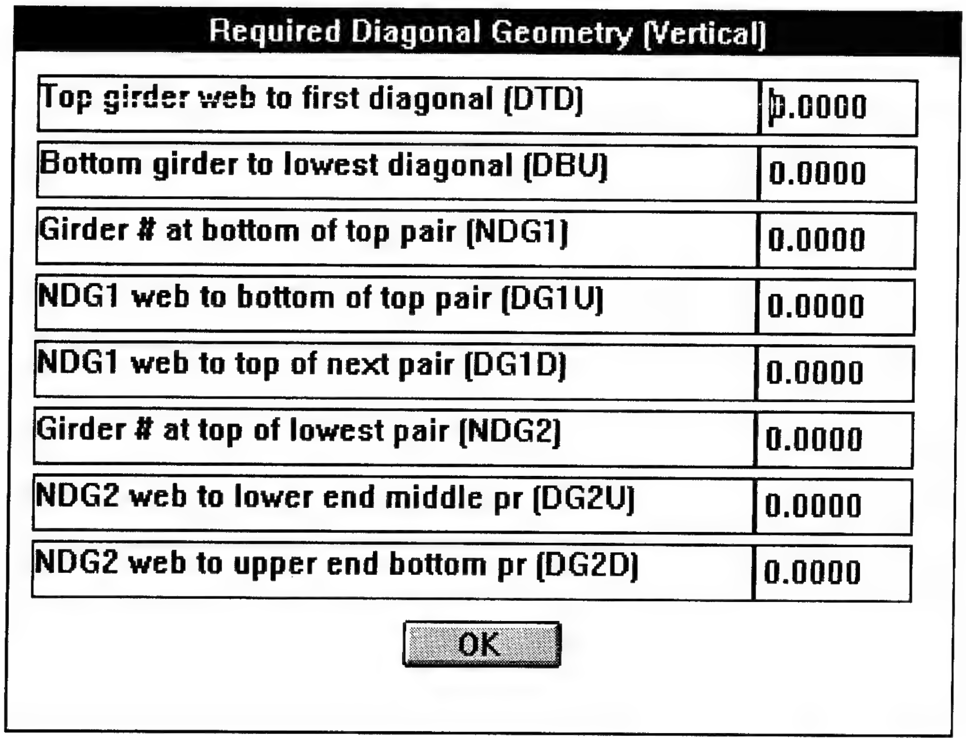


Figure 65. Vertical diagonals input window

DTD = distance from topmost girder web down to highest diagonal end.

DBU = distance from bottom girder web up to lowest diagonal end.

NDG1 = girder number at the bottom of the topmost diagonal pair panel (use if NDPV is two or three).

DG1U = distance from the web of the girder NDG1 up to lower end of diagonal pair in the topmost diagonal panel (use if NDPV is two or three).

DG1D = distance from the web of the girder NDG1 down to the upper end of diagonal pair in the diagonal panel inmediately below the girder (use if NDPV is two or three).

NDG2 = girder number at the top of the bottom diagonal panel, the third diagonal panel (use if NDPV is three).

DG2U = distance from the web of the girder NDG2 up to lower end of diagonal pair in the middle diagonal panel.

DG2D = distance from the web of the girder NDG2 down to the upper end of diagonal pair in the bottom diagonal panel.

Required diagonal geometry (offset)

The diagonals offset input window (Figure 66) defines the horizontal offset from the skin plate to the diagonals. Values are in inches.

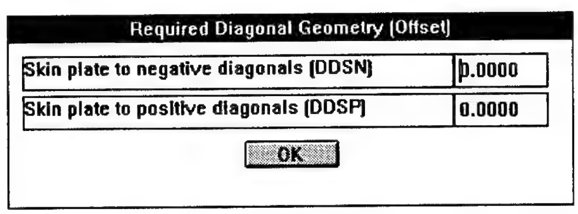


Figure 66. Diagonals offset input window

DDSN = distance from downstream face of skin plate to center line of negative diagonals.

DDSP = distance from downstream face of skin plate to center line of positive diagonals.

Group 4

Group 4 is required only if the user wants to change the default values used for certain items and when the load combination 6 is active. Following is the sequence to generate data Group 4 using the graphic interface.

To start the graphic interface for data Group 4, the user should select the **Group 4** from the **Input** option (Figure 67).

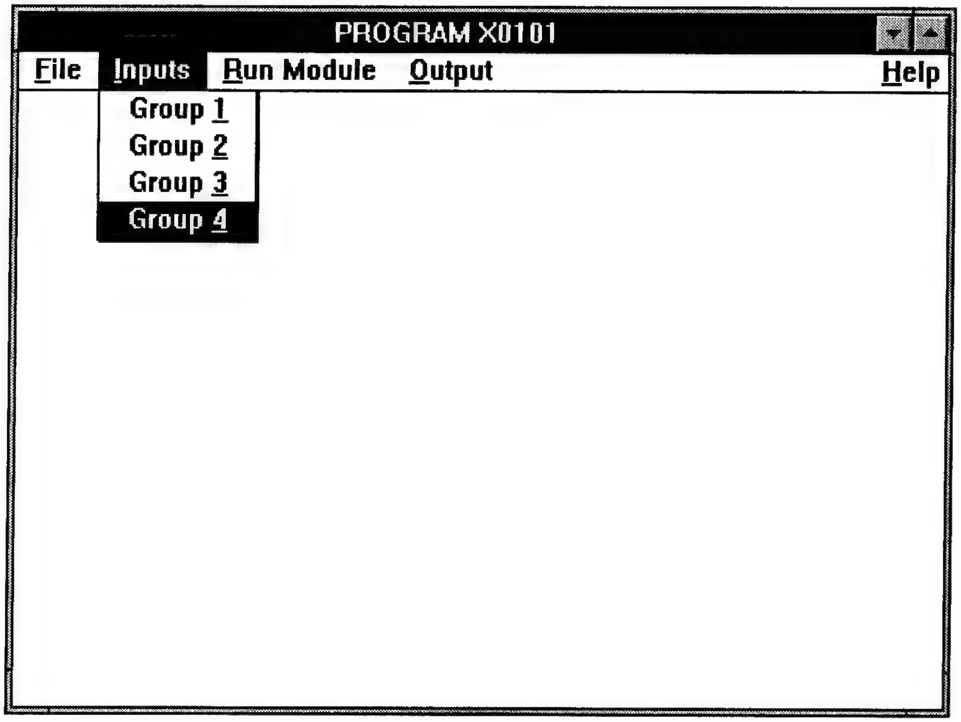


Figure 67. Beginning of graphic interface for data Group 4

Design minimum thickness input window

Each item in this list (Figure 68) includes the default value that is specified if the list is not entered. Values are in inches.

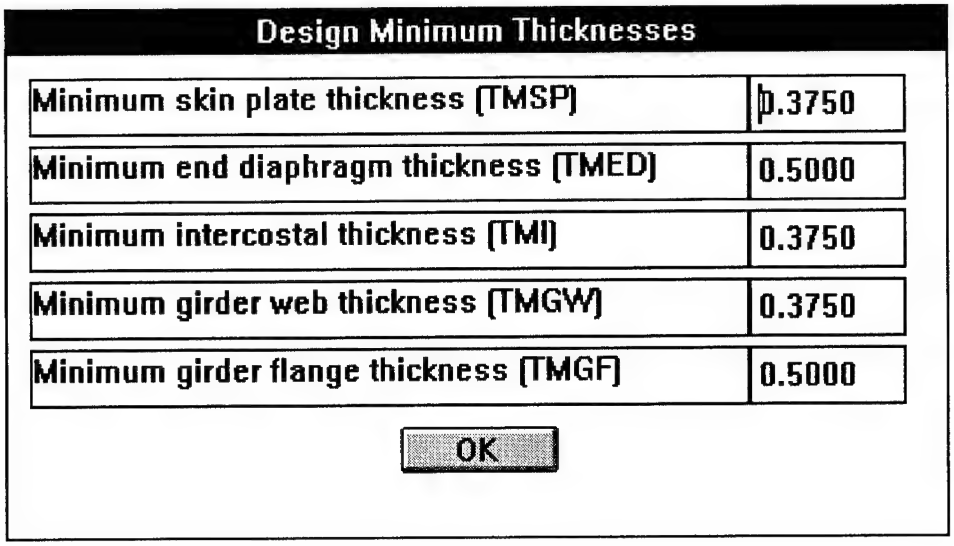
TMSP = minimum thickness of skin plate (SPT in data list ISG (Group 2)). Default value = 0.375 in.

TMED = minimum thickness of end diaphragms (EDT in data list RED (Group 3)). Default value = 0.5 in.

TMI = minimum thickness of intercostal (data list ISG (Group 2)). Default value = 0.375 in.

TMGW = minimum thickness of girder webs (GWET and GWCT in data list GWT (Group 2)). Default value = 0.375 in.

TMGF = minimum thickness of girder flanges (data groups GFU and GFD (Group 2)). Default value = 0.5 in.


Design Minimum Thicknesses

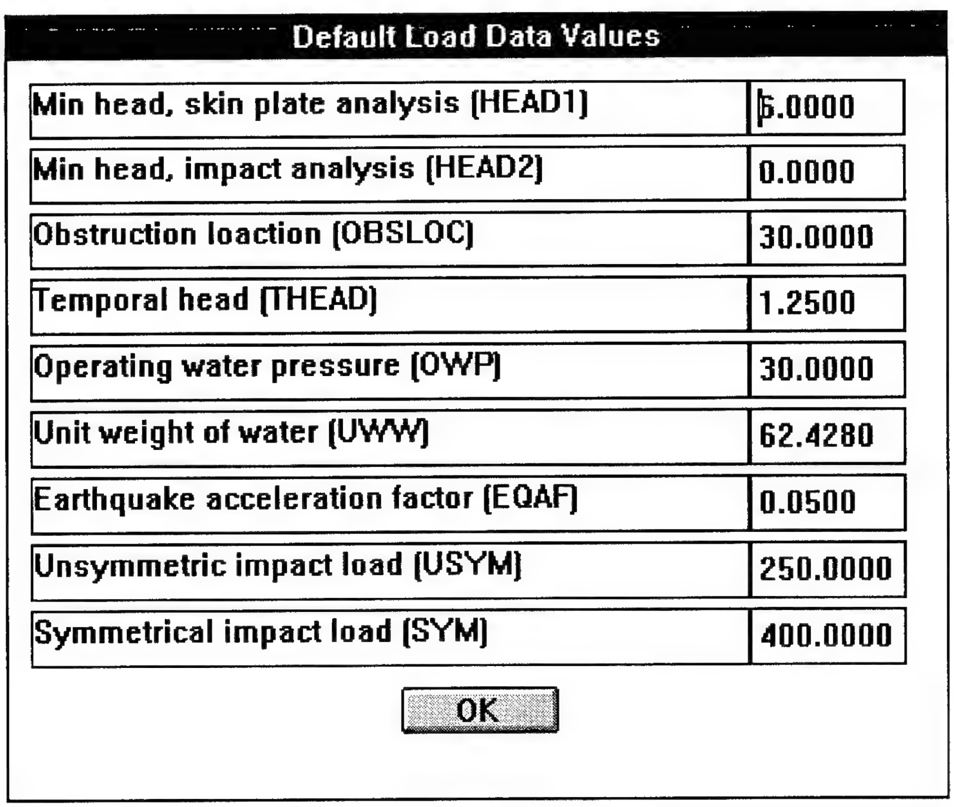
Minimum skin plate thickness (TMSP)	0.3750
Minimum end diaphragm thickness (TMED)	0.5000
Minimum intercostal thickness (TMI)	0.3750
Minimum girder web thickness (TMGW)	0.3750
Minimum girder flange thickness (TMGF)	0.5000

OK

Figure 68. Default minimum thickness input window

Default load data values input window

This data list (Figure 69) allows changing the default values for hydraulic and impact load data.


Default Load Data Values

Min head, skin plate analysis (HEAD1)	5.0000
Min head, impact analysis (HEAD2)	0.0000
Obstruction loaction (OBSLOC)	30.0000
Temporal head (THEAD)	1.2500
Operating water pressure (OWP)	30.0000
Unit weight of water (UWW)	62.4280
Earthquake acceleration factor (EQAF)	0.0500
Unsymmetric impact load (USYM)	250.0000
Symmetrical impact load (SYM)	400.0000

OK

Figure 69. Default loads input window

HEAD1 = feet of water to be used as a minimum head for analysis of skin plate. Default value = 6.0 ft.

HEAD2 = feet of water to be used as a minimum head for impact analysis of girders in ASD criteria. A value of zero is used in LRFD criteria.

OBSLOC = obstruction location radius from pintle, feet. If not changed by data group DEF, the default value will be placed at the miter point. Use any number if STRUTF = 0.

THEAD = temporal head, feet of water, applied from the full submergence elevation ELFS down to the gate bottom. Default value = 1.25 ft.

OWP = operating water pressure, pounds per square foot, applied from the operating water elevation ELOW to the gate bottom. Default value = 30.0 psf.

UWW = unit weight of water, pounds per cubic foot. Default value = 62.5 pcf.

EQAF = earthquake acceleration factor to be used in Westergaard's equation to determine dynamic water pressures. Default value = 0.05.

USYM = unsymmetric impact load, kips. Default value = 250.0 kips.

SYM = symmetric impact load, kips. Default value = 400.0 kips.

5 Example Problem

Scope

This chapter presents an example that will help to create and clarify the input and output files for each module, the program execution that explains how to run and interact with the program, the hand calculation procedure for each structural element, and the computer results.

The miter gate of this example is the lower gate at Lock and Dam No. 3 on Red River Waterway. The gate spans an 84-ft-wide lock, with a differential head of 31 ft. In the example, for the design of the lower miter gate, an intercostal plate section and a noncompact girder section are designed. Program results for the example are shown with a text editor format in Riveros (1995) (ITL-95-1).

Example, Lower Miter Gate

RECDES module input file

The input file used in this example to run the RECDES module includes Groups 1 and 4.

These input files represent the optimum files that were obtained by the program previously. The windows sequence used to create the input file to run the RECDES module is as follows. (See Figures 70-84.)

Data Group 1

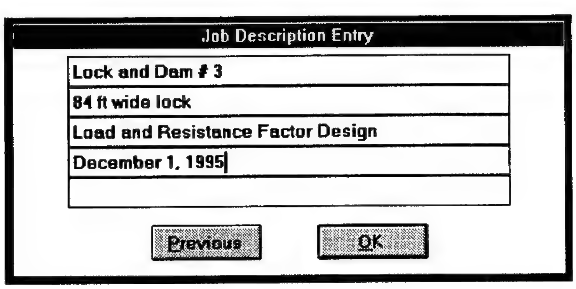


Figure 70. Job description

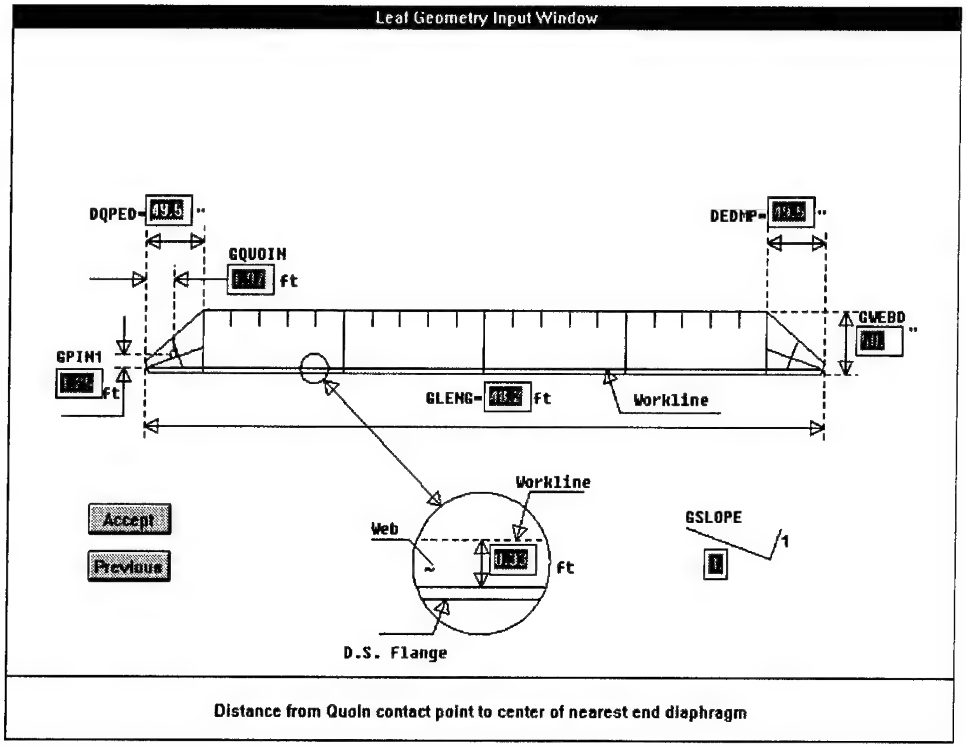


Figure 71. Leaf geometry values

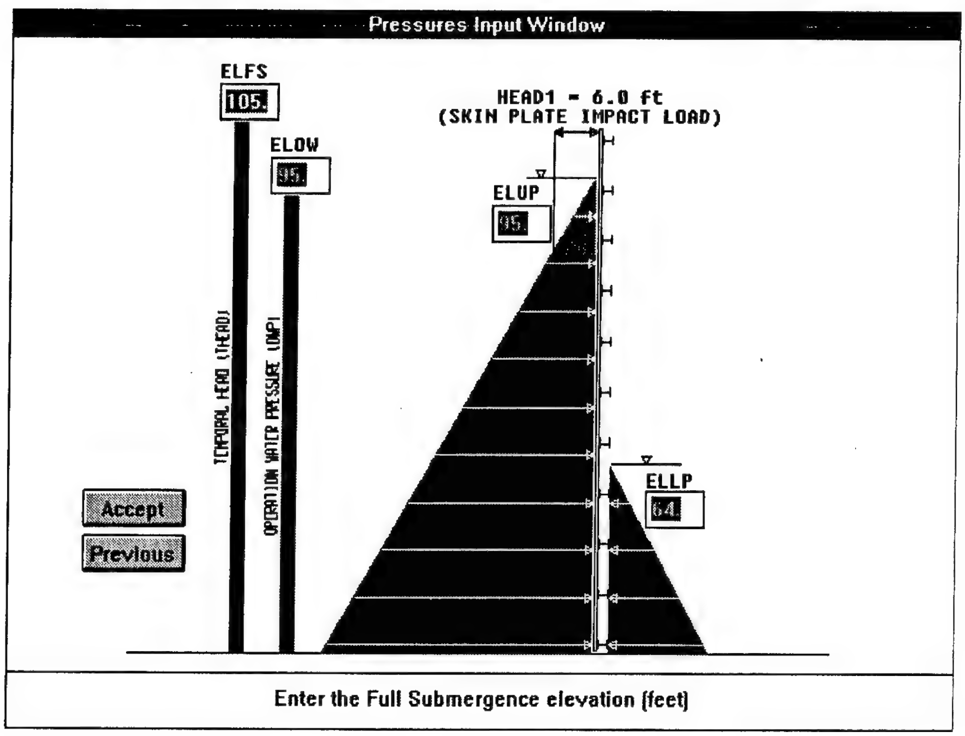


Figure 72. Pressures values

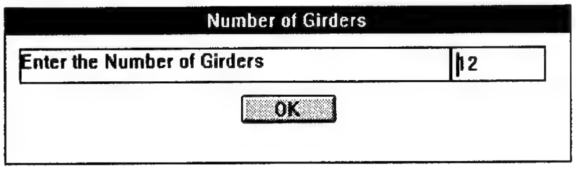


Figure 73. Number of girders

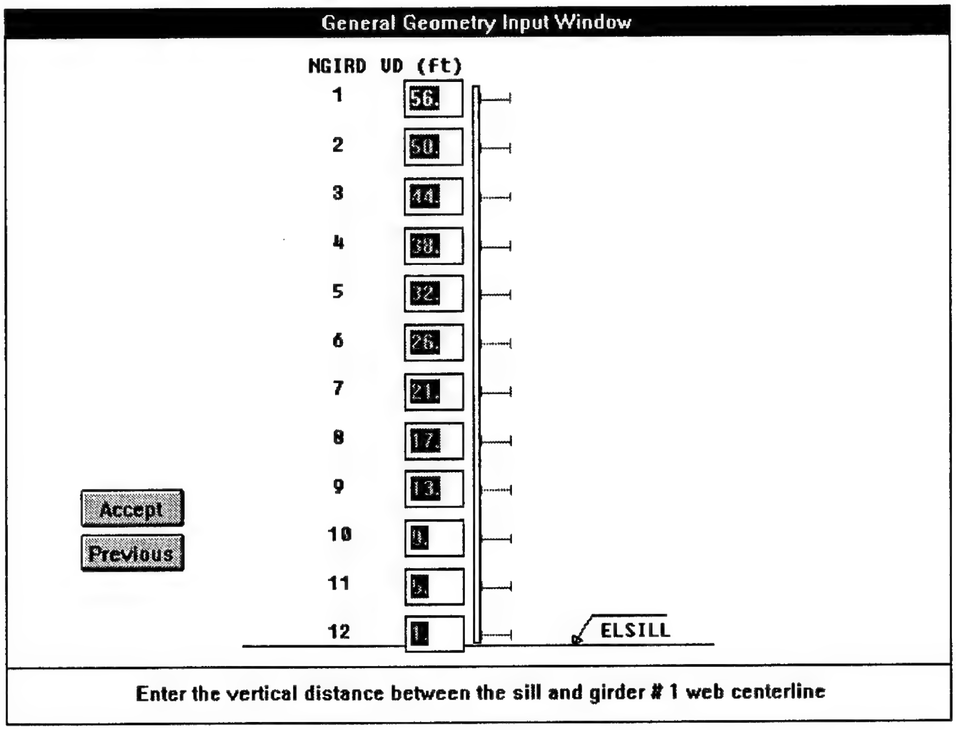


Figure 74. General geometry values

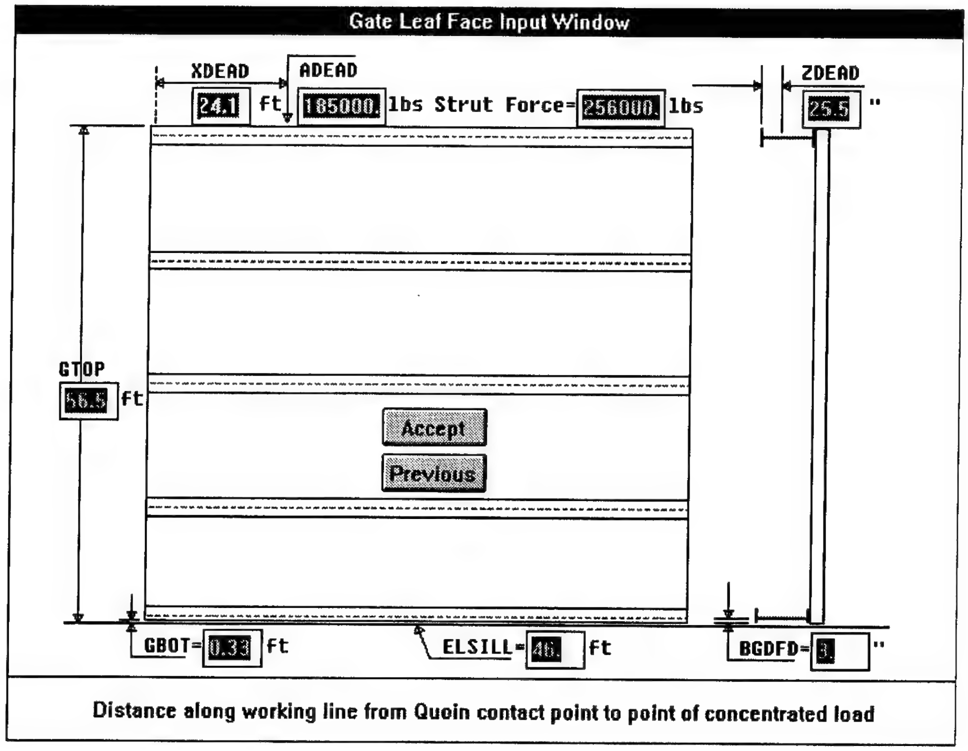


Figure 75. Gate leaf values

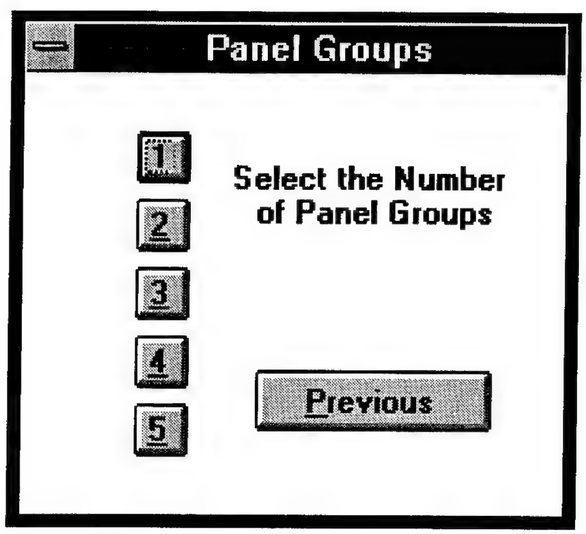


Figure 76. Number of panel groups

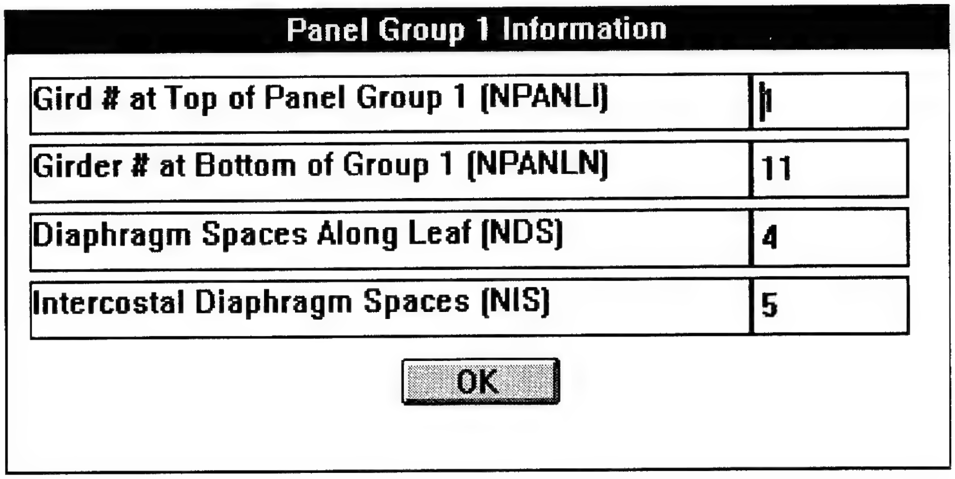


Figure 77. Panel Group 1 information

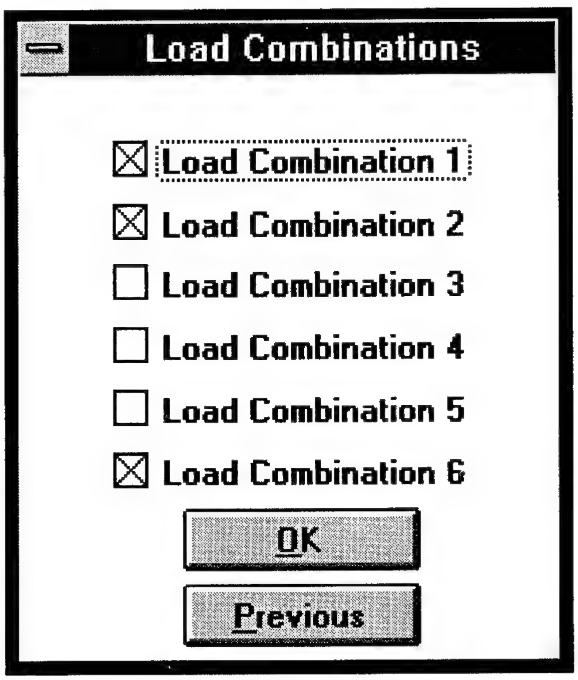


Figure 78. Active load combinations

Steel Yield Strengths (Ksi)

All Other Steels Not Specified (FY)	36.0000
In The Girder Webs (FYW)	36.0000
In The Girder Flanges (FYF)	36.0000
In The Skin Plate (FYSK)	36.0000
In The Girder Stiffeners (FYS)	36.0000
In The Intercostals (FYI)	36.0000
In The Quoin Post (FYQ)	36.0000
In The Diagonals (FYD)	60.0000
Maximum Diagonal Tensile Strength (FUD)	75.0000

OK

Figure 79. Steel yield strengths

Fatigue Category Values

Gate Load Condition (LC)	2
Skin Plate Fatigue Category (CATSK)	C
Intercostal Fatigue Category (CATI)	B
Girder Fatigue Category (CATG)	C
Diaphragm End Girder Category (CATGE)	C

OK

Figure 80. Fatigue values

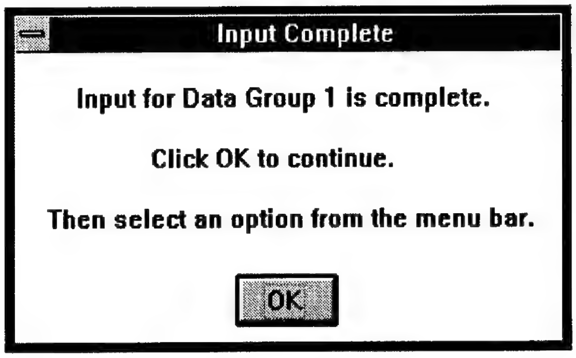


Figure 81. Input data Group 1 completed

Data Group 4

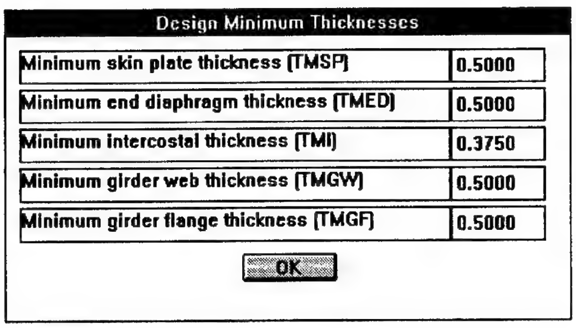


Figure 82. Minimum thicknesses

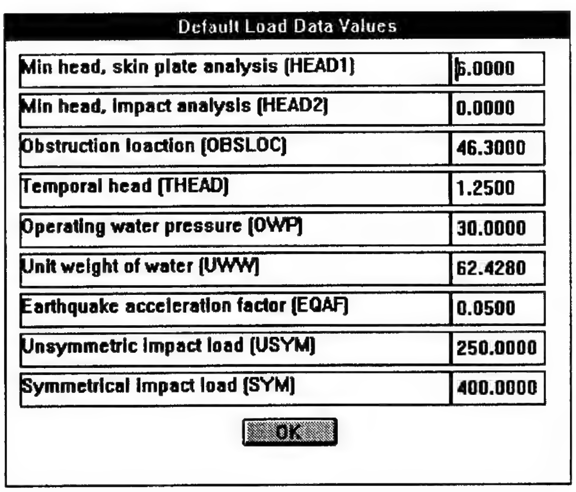


Figure 83. Loads values

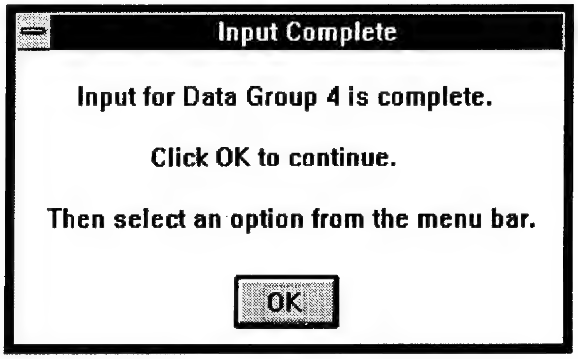


Figure 84. Input data Group 4 completed

RECDES module program execution

To run the RECDES module press **Recommended Design** from the **Run Module** option (Figure 85). The windows sequence that will appear when RECDES module is executed follows. (See Figures 86-91.)

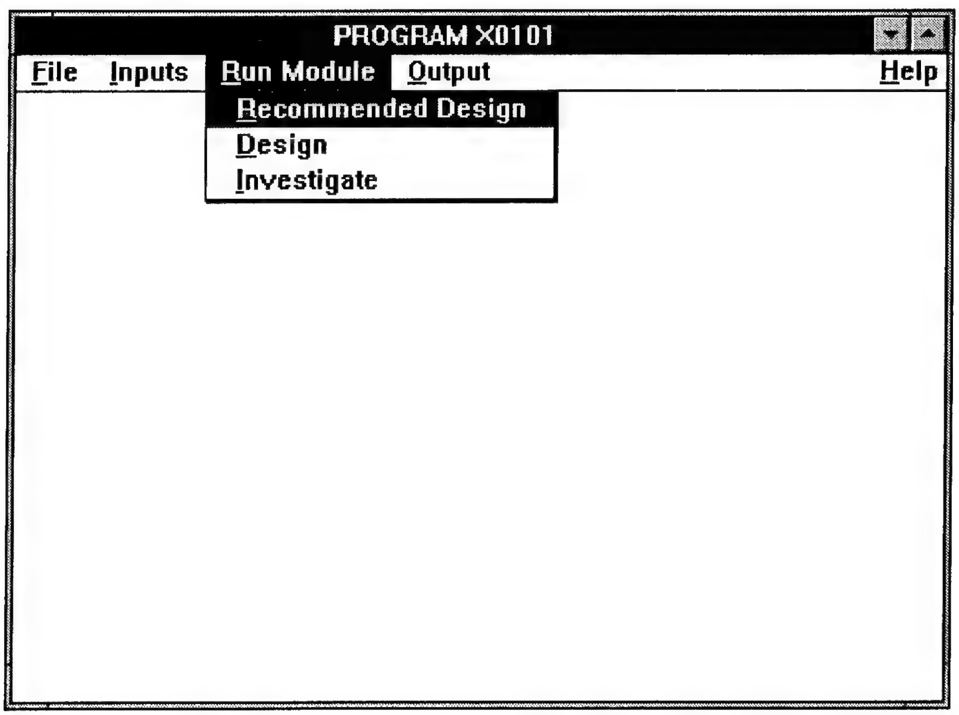


Figure 85. RECDES module execution window

a. Enter output file name where the results should be written.

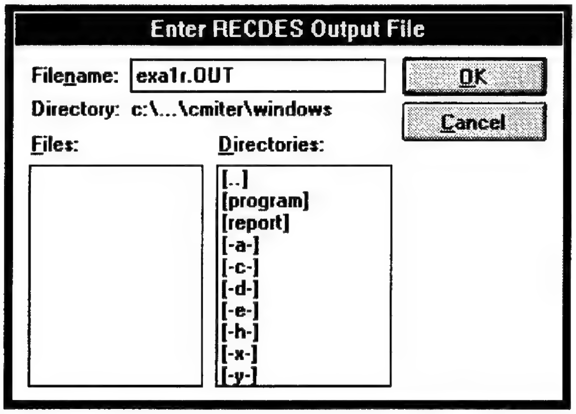


Figure 86. RECDES output file name window

b. Enter minimum and maximum girder spacings. The spacing of the girder to have the same uniform loads will be found with these two values. The values should be between 4 and 7 ft (EM 1110-2-2703).

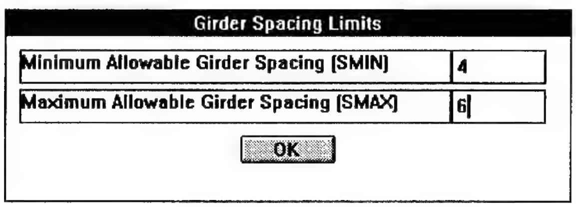


Figure 87. Minimum and maximum girder spacings

c. Enter panel number desired or "0" for all panels. The user can select the panels to investigate, or all the panels will be available if "0" is selected.

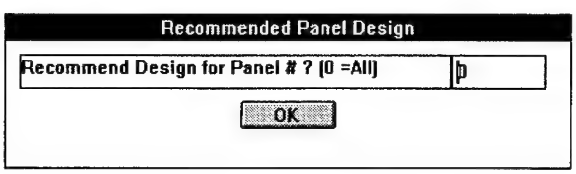


Figure 88. Recommended panel design window

d. What girder section do you want to design?

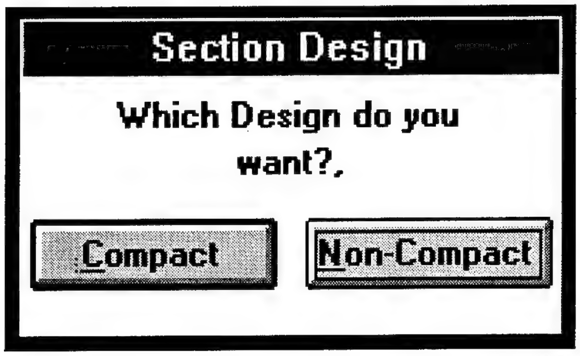


Figure 89. Compact or noncompact girder design window

e. Girder number desired or “0” for all girders. The user can select the girder to investigate, or all the girders will be available if “0” is selected.

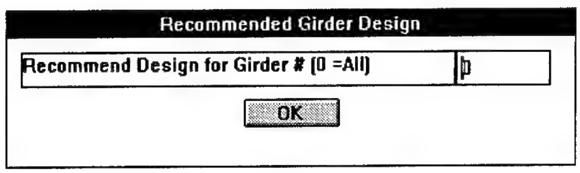


Figure 90. Recommended girder design window

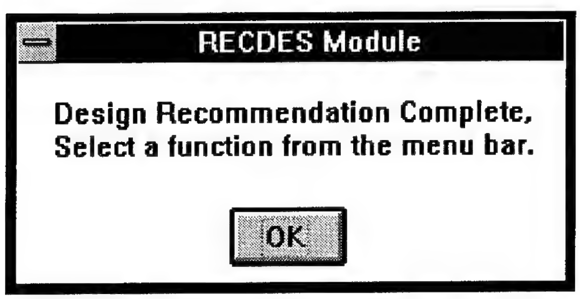


Figure 91. RECDES module completed window

RECDES module output file

The output files of the example in a text editor format are included in Riveros (1995) (ITL-95-1). The output file of the RECDES module is listed below.

a. Required input data. All the data from the input file are in this section with a corresponding description. Following are the screens provided by the output interface. The user can use this option before the execution of the module to verify the input data. (Figures 92-98.)

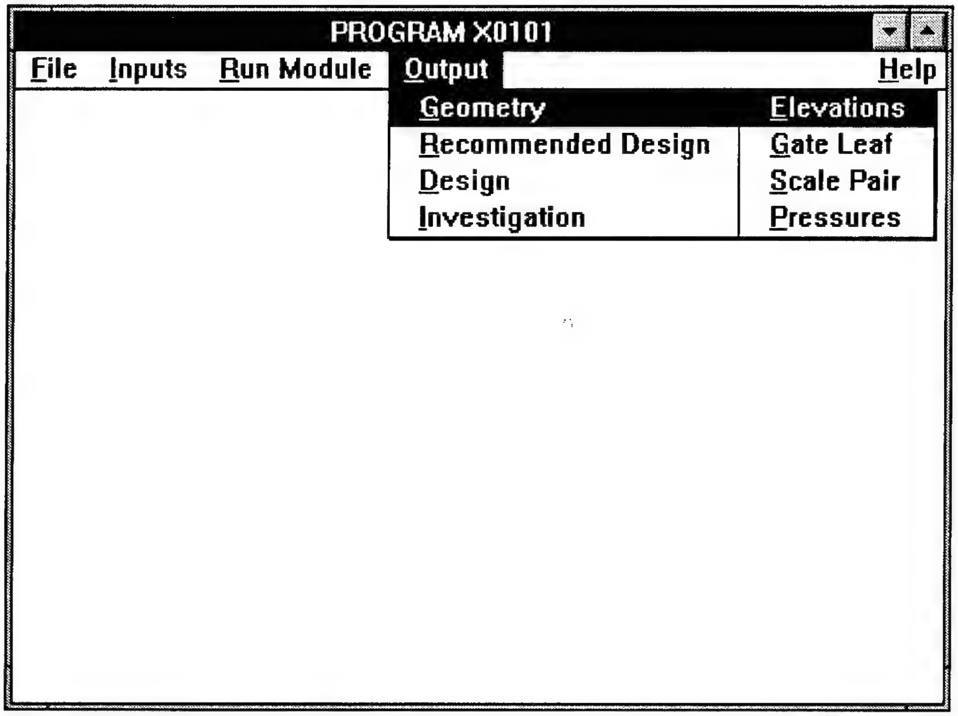


Figure 92. Output geometry option

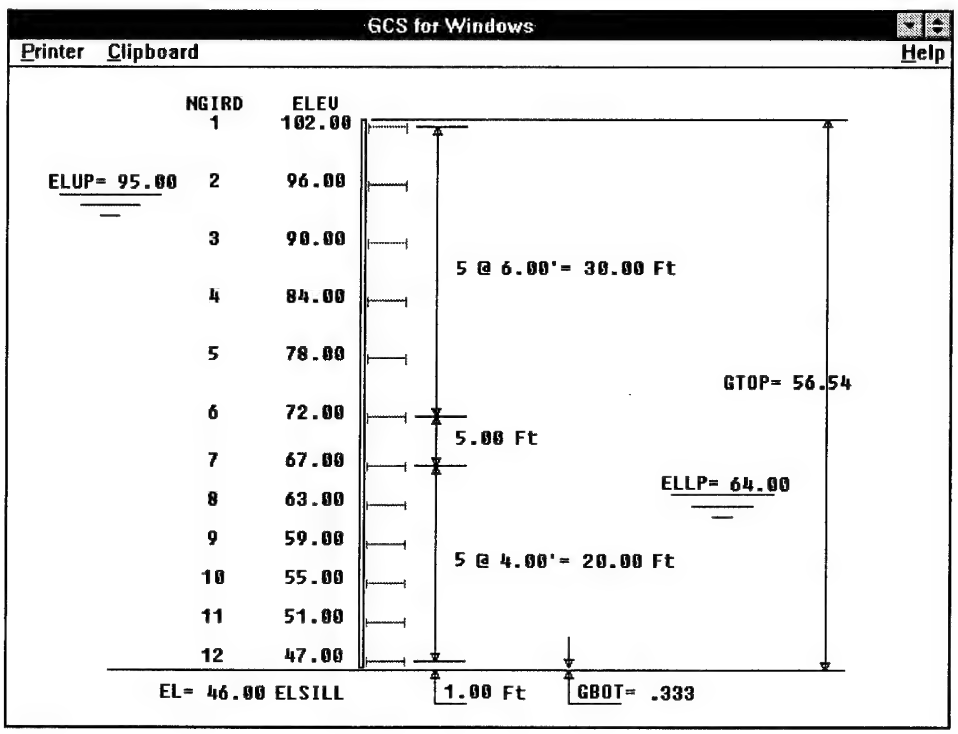


Figure 93. Geometry elevations

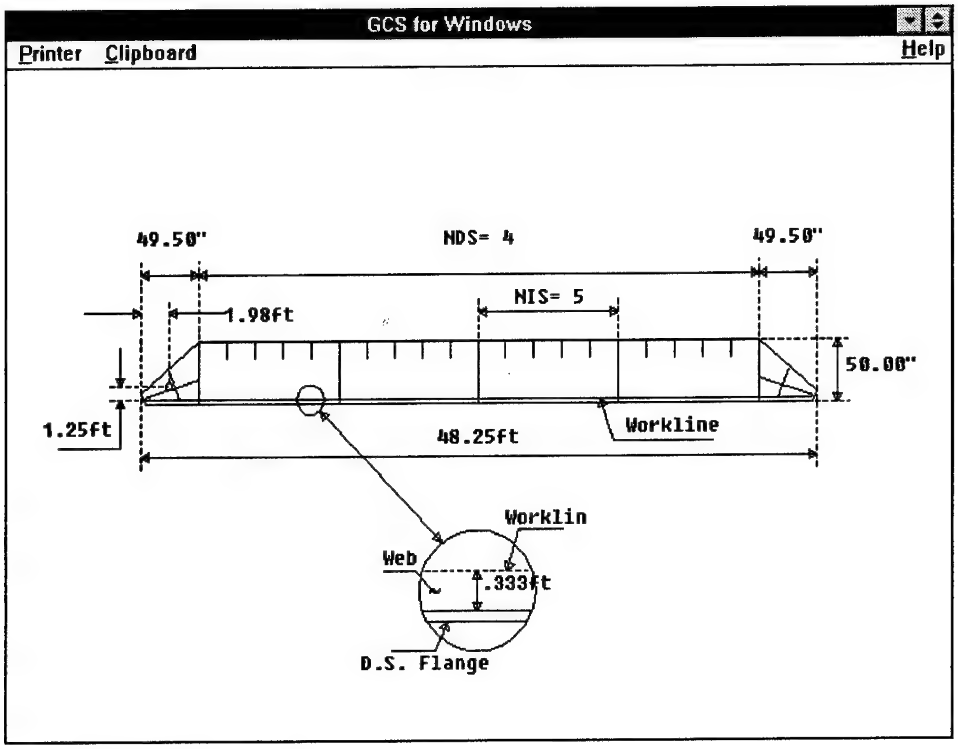


Figure 94. Geometry girder leaf

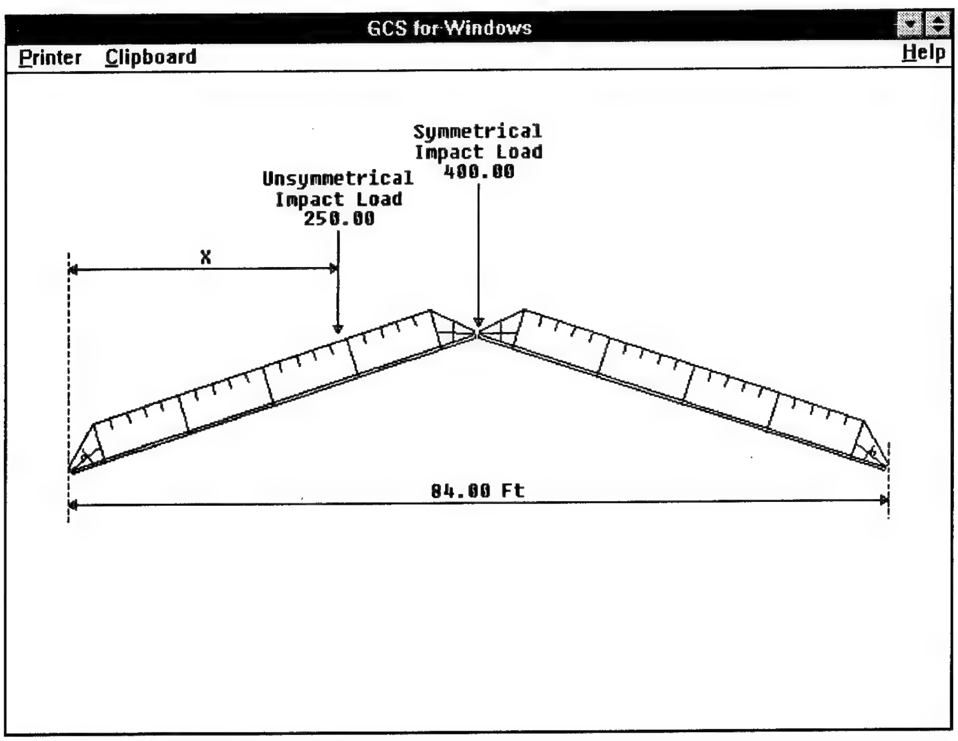


Figure 95. Geometry scale pair

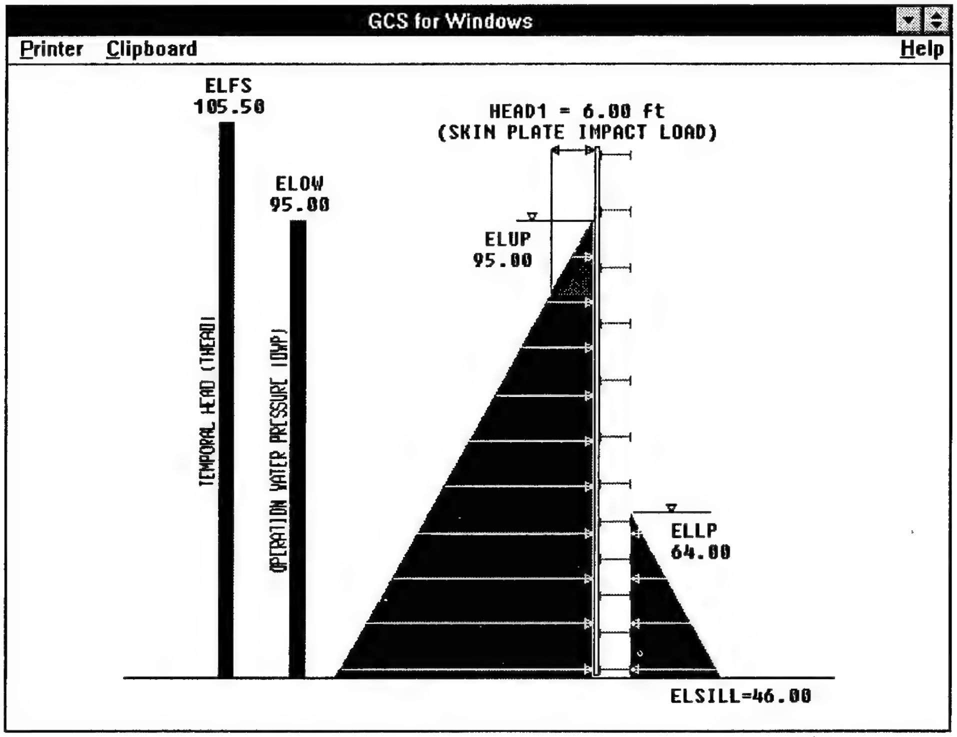


Figure 96. Geometry pressures

b. Recommended girder location's table to yield approximately equal loads. The program determines the optimum girder location using load combination 1. The optimum girder location occurs when the girders have approximately equal loads. The figure below compares the girder location specified by the user with the girder location calculated by the program (Optimum). The girder spacing calculated by the program will be shown in different colors (green, blue, red) representing the difference in spacing between the girder suggested by the user and the girder calculated by the program.

Red Spacing Difference > 0.5 ft

Blue 0.25 < Spacing Difference ≤ 0.5

Green 0.05 < Spacing Difference ≤ 0.25

c. Girder load table. With the girder position from the input file, the program finds the loads acting in each girder for the active load combinations. Here the designer has to compare the results in the tables with the results of the recommended girder locations table and redefine the input file if desired to reach the same uniform load in each girder.

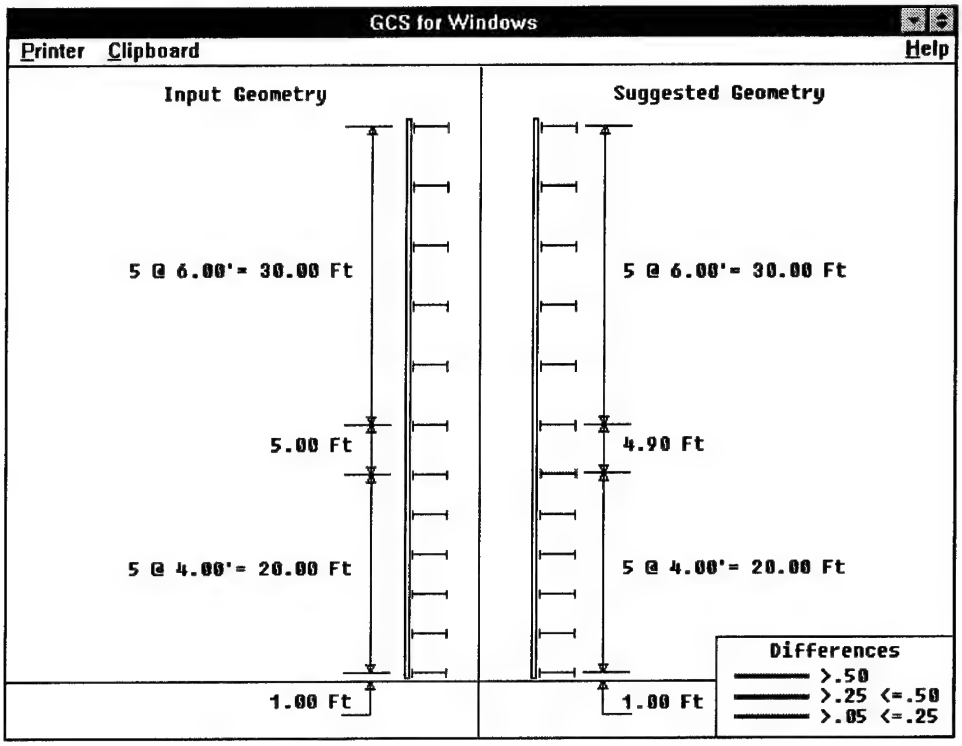


Figure 97. Recommended girder location

d. *Recommended skin plate thickness and intercostal size and spacing to determine the optimum weight.* The output file tables suggest a skin plate thickness for different numbers and sizes of intercostals. Here the designer should decide what is the best combination of skin plate and intercostal. This decision can be based on the total panel weight.

e. *Recommended girder web depth.* The output file tables suggest different girder web depths for each girder. The designer has to decide the best alternative by checking the weight of the girders.

f. *Total weight of the girders with the same web depth.* This output file is the summation of the weight of each girder with all girders having the same web depth. These output tables provide the user with information on which girder web depth should be used in the design module. Figure 98 shows an X-Y graph presenting these results.

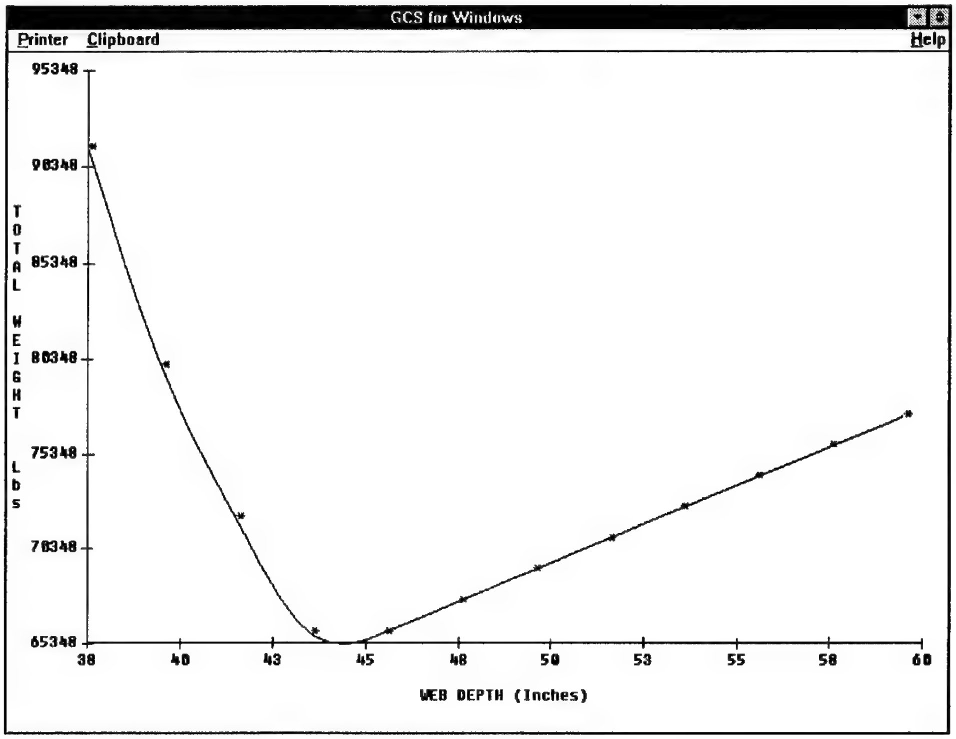


Figure 98. Girder web depth versus weight

DES module input file

The input file used is the same as the input file used in the RECDES module, along with Group 3 as shown in Figures 99-107.

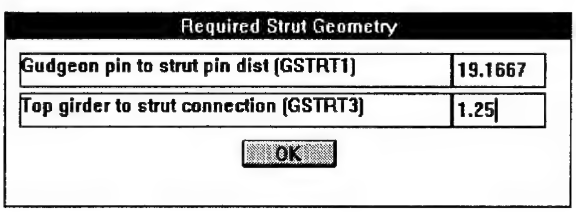


Figure 99. Strut geometry

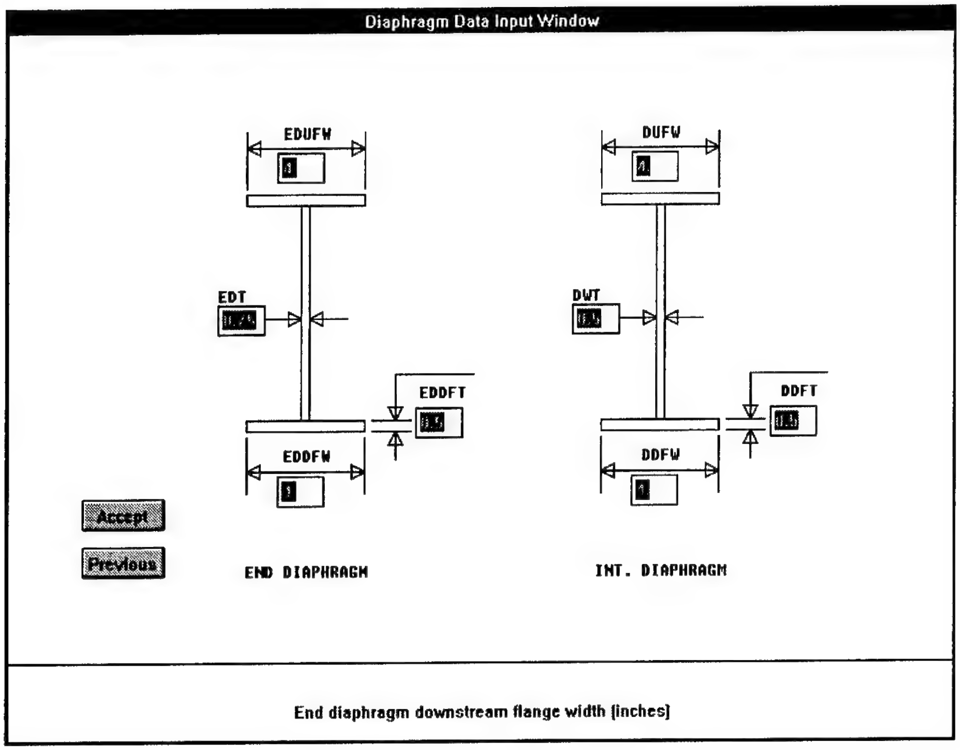


Figure 100. Diaphragm values

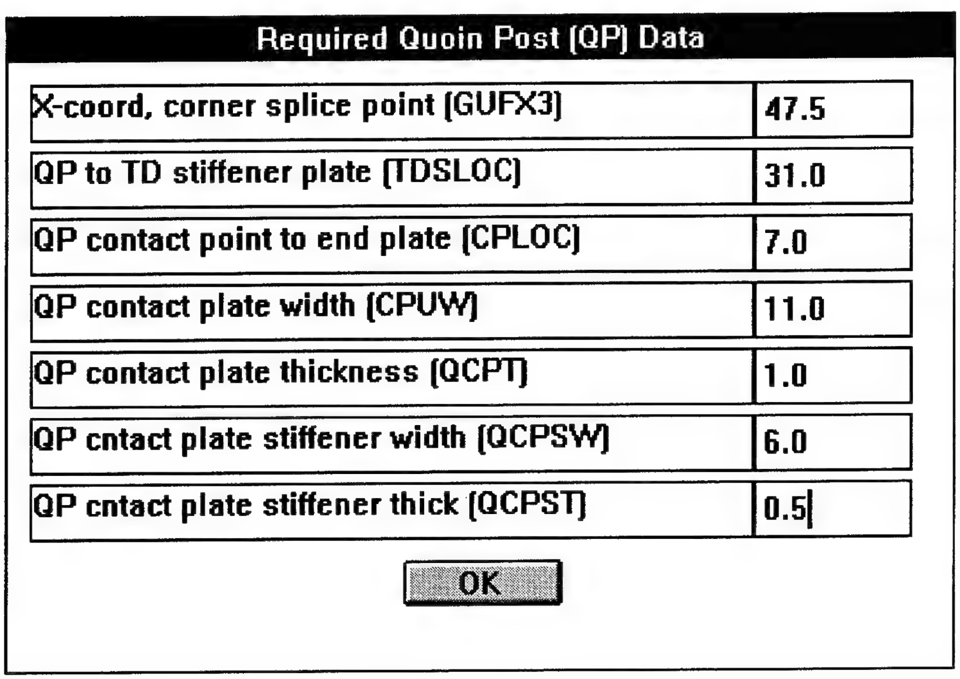


Figure 101. Quoin post values

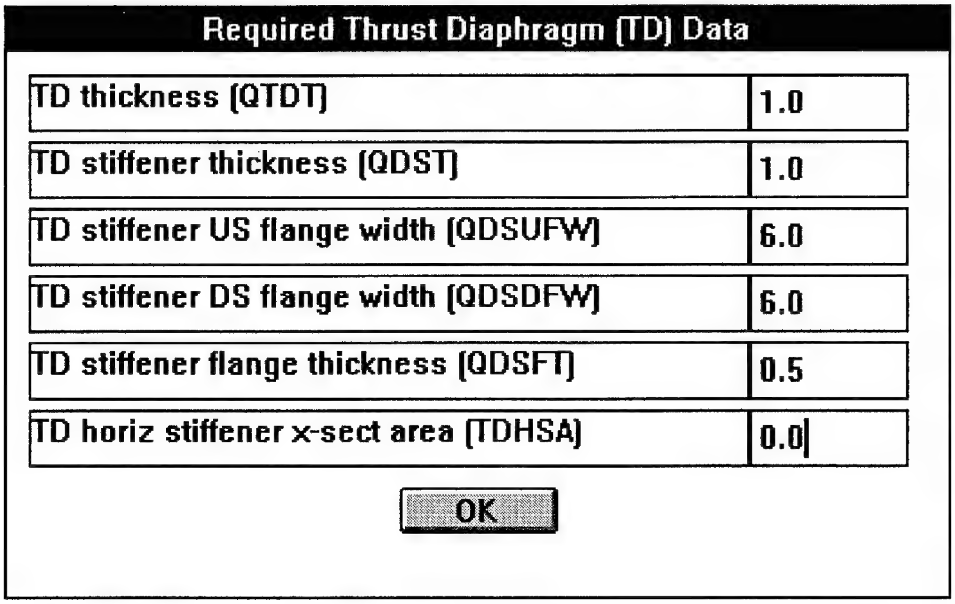


Figure 102. Thrust diaphragm values

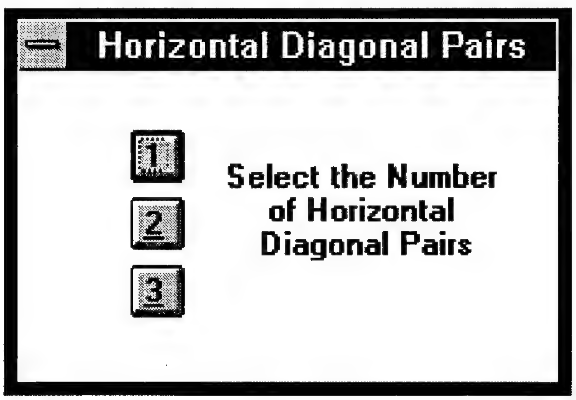


Figure 103. Number of horizontal diagonal pairs

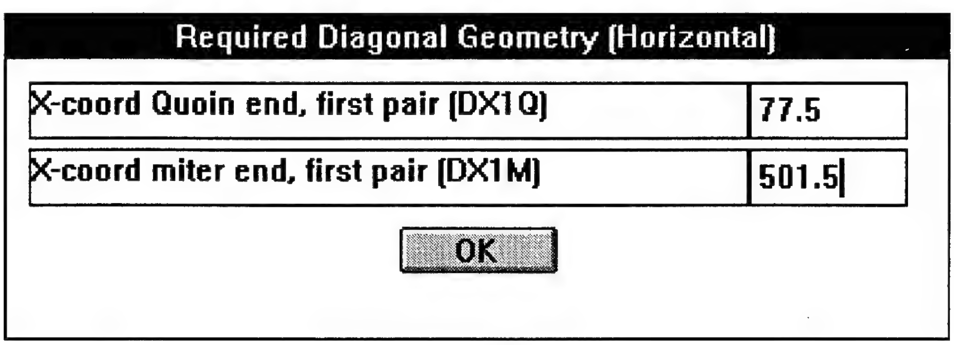


Figure 104. Diagonal geometry values (horizontal)

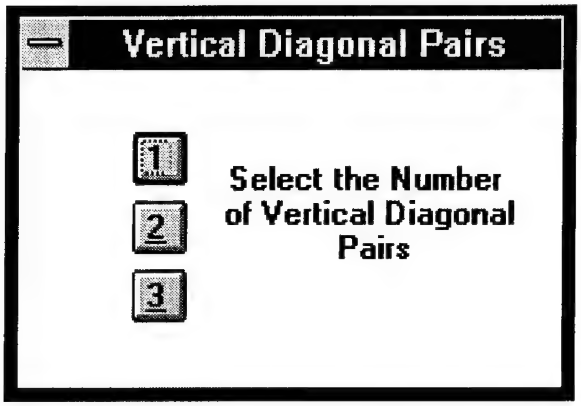


Figure 105. Number of vertical diagonal pairs

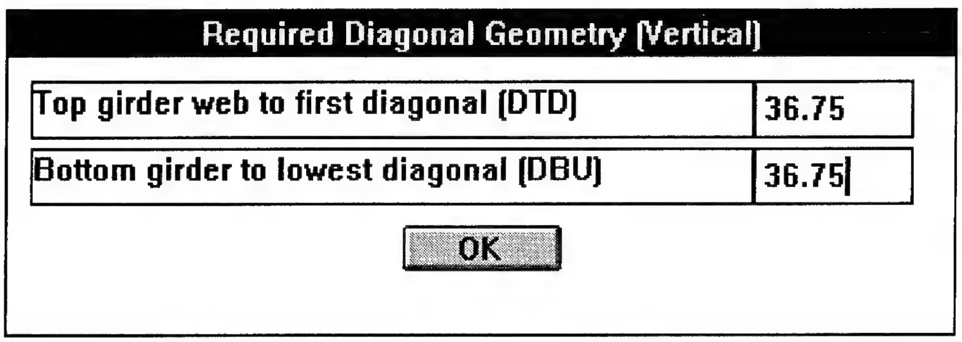


Figure 106. Diagonal geometry values (vertical)

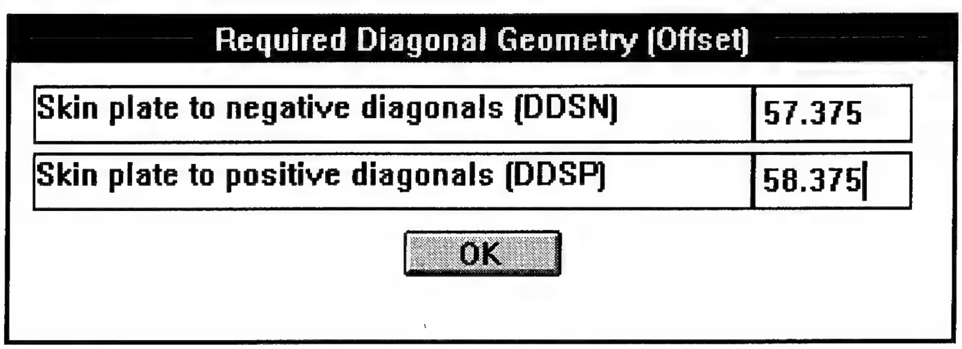


Figure 107. Diagonal geometry (offset)

Save input file

Because the input file to run RECDES module has been edited, the new input file should be saved. The sequence of windows used to save the input file required to run the DES module is shown in Figures 108 through 110.

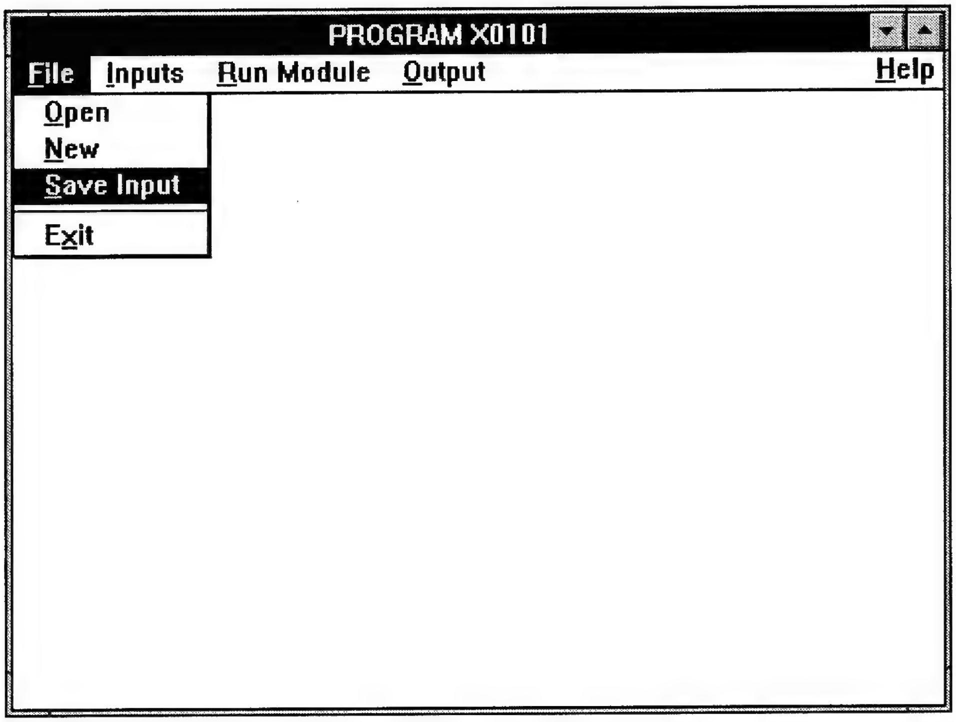


Figure 108. Save input window

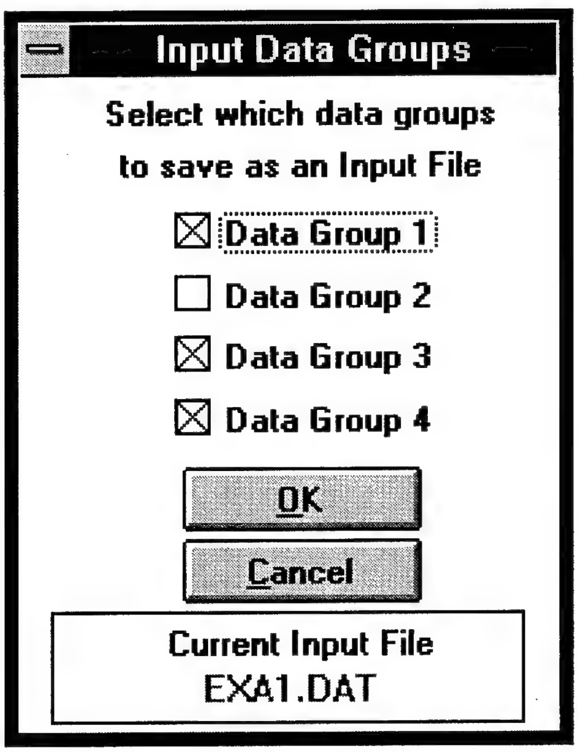


Figure 109. Data groups to be saved

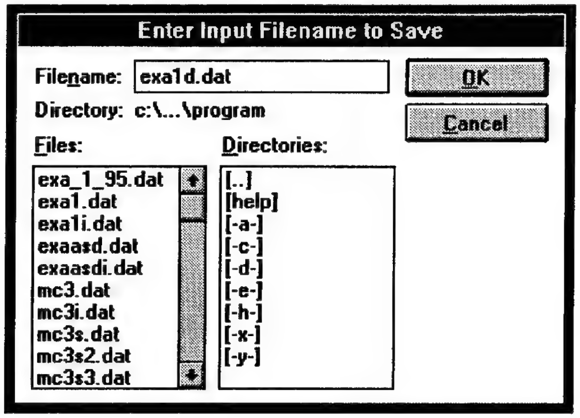


Figure 110. Input file name

DES module program execution

To run the DES module press **Design** from the **Run Module** option (Figure 111). The windows sequence that will appear when DES module is executed follows (Figures 112-114).

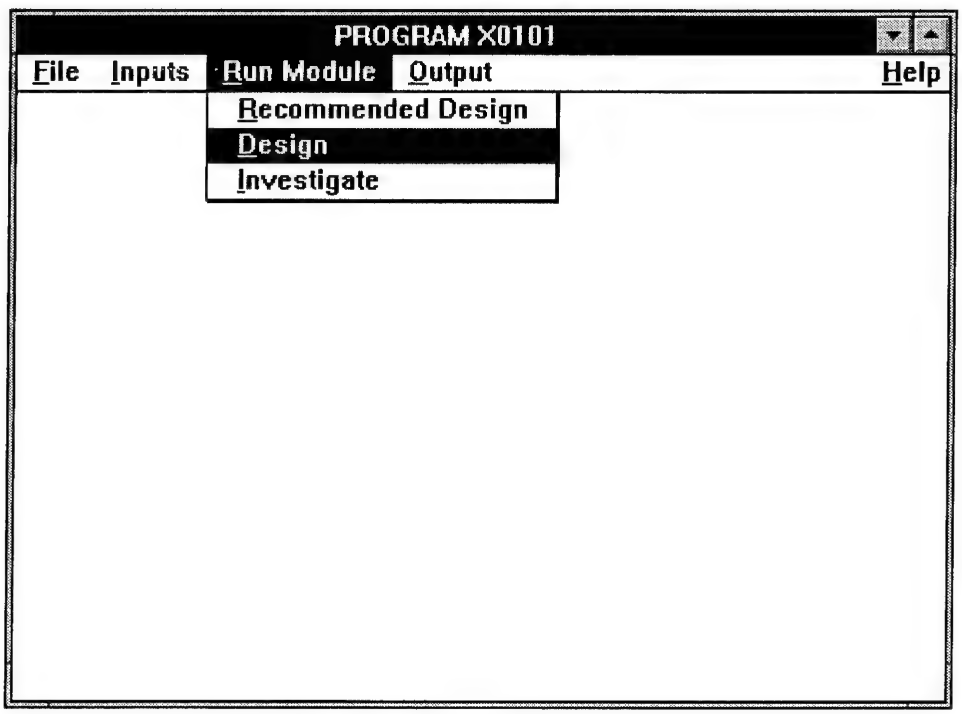


Figure 111. DES module execution

a. Enter output file name.

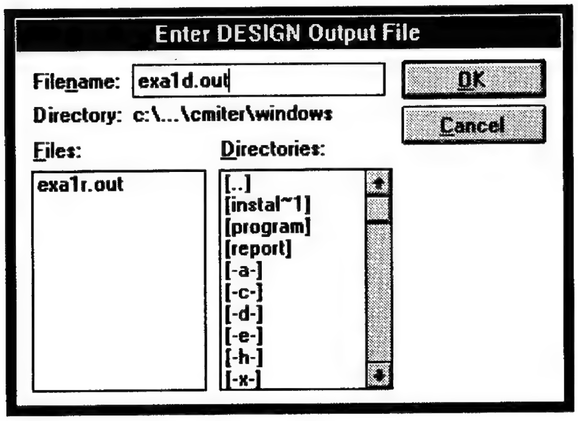


Figure 112. Output file

b. What type of girder section do you want to design?

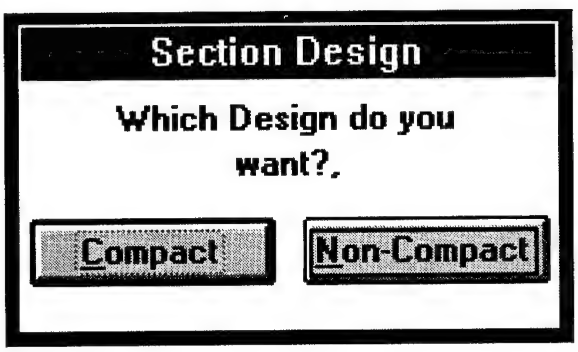


Figure 113. Plate girder design

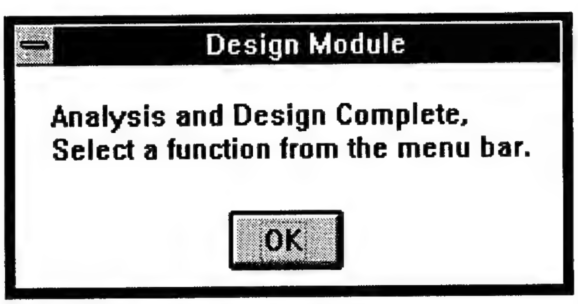


Figure 114. DES module execution completed

DES module output file

The DES module output file provides the required widths and thicknesses of all plates used to build the elements of the gate. Figure 115 shows the graphic interface that can be selected from the program followed by the output file list.

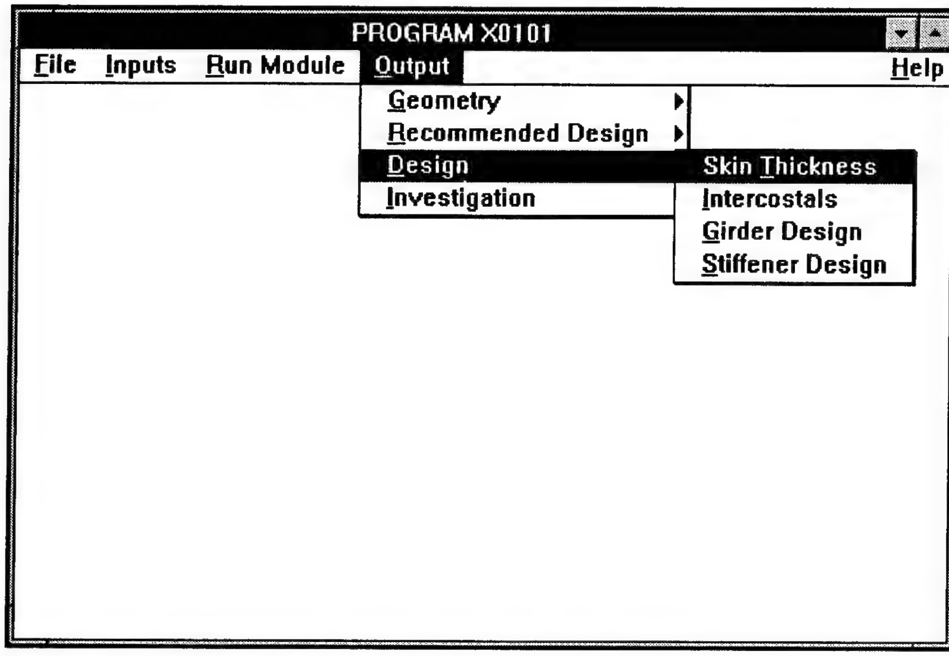


Figure 115. Design output interface options

a. *Required input data.* All the data from the input file are in this section with a corresponding description.

b. *Skin plate design.* The window for skin plate design is shown in Figure 116.

c. *Intercostal design.* The user can move to the next or previous panel by pressing **Next** or **Previous**, or return to the main menu by choosing **Menu** (Figure 117).

d. *Girder design.* This output file window shows the dimensions required for the section at the girder center line and end diaphragm section (Figure 118). The user can move to the next or previous girder pressing **Next** or **Previous**, or return to the main menu if he chose **Menu.**

e. *Flange splice distances.* These are the distances to the splice points on the girder flanges from the contact point.

f. *Web stiffeners.* The user can move to the next or previous girder by pressing **Next** or **Previous** or return to the main menu by pressing **Menu** (Figure 119).

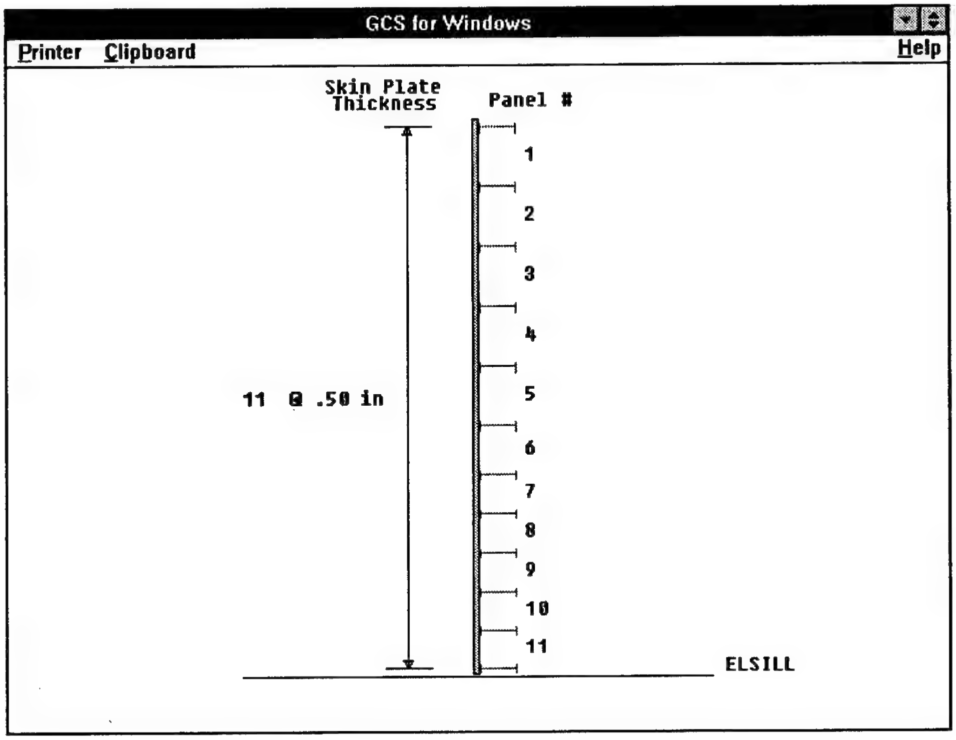


Figure 116. Skin plate design

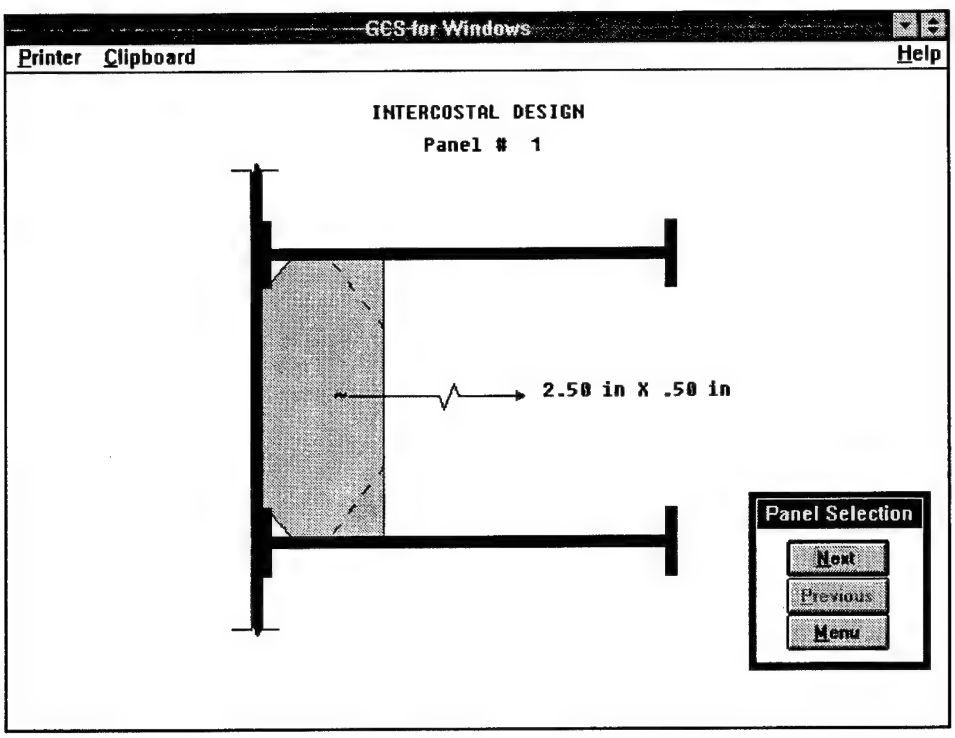


Figure 117. Intercostals design

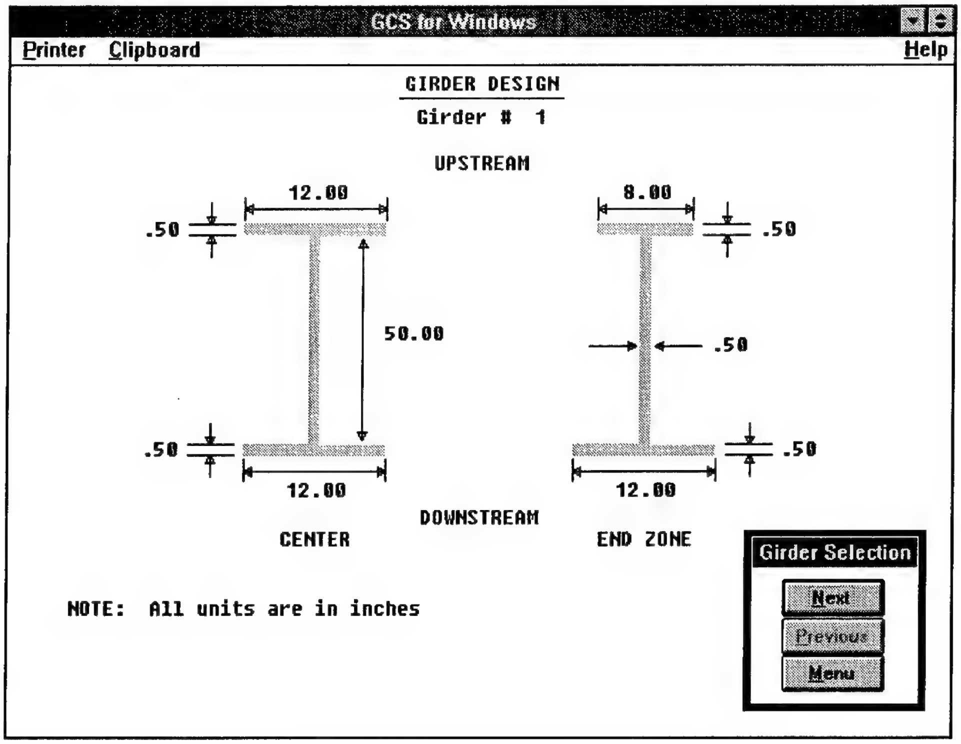


Figure 118. Girder design

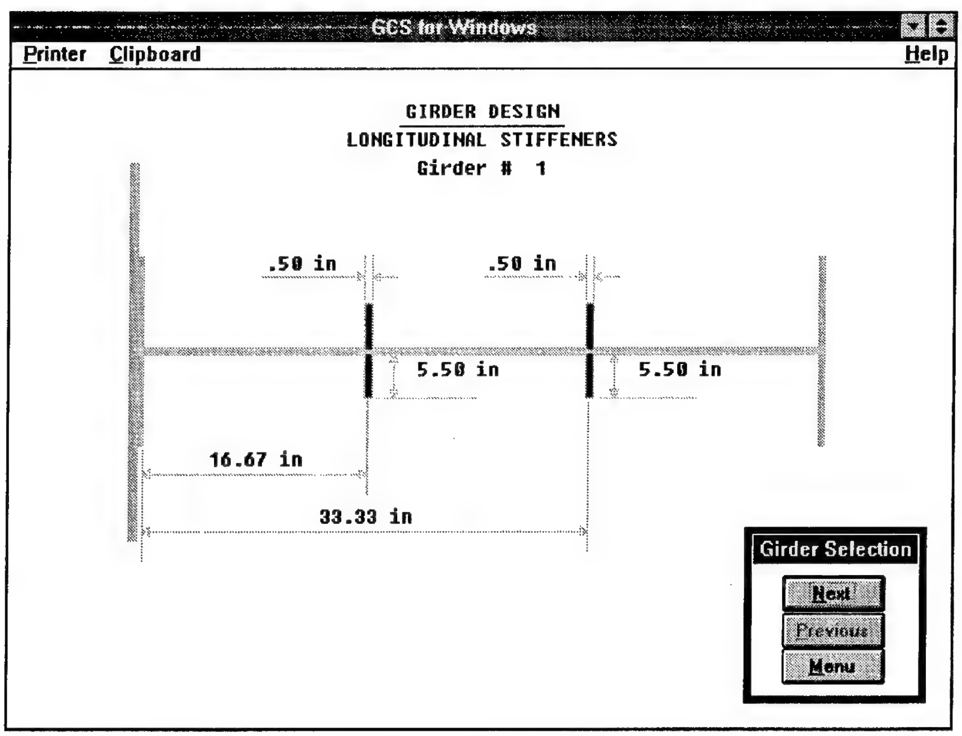


Figure 119. Longitudinal stiffeners design

g. End diaphragm design. This option includes the end diaphragm dimensions.

h. Quoin post design. This option includes the quoin post properties, dimensions, and stresses for the points shown in Figure 15.

i. Thrust diaphragm design. This option includes the thrust diaphragm dimensions.

j. Tapered end design. This option includes the tapered end section dimensions.

k. Diagonal design. This option includes the diagonal parameters required by EM 1110-2-2703 and the required diagonal areas.

l. Gate properties. This option presents the weight and the center of gravity of the gate leaf.

INV module input file

The input file to run the investigation module includes the four data groups. The input file used is the same as that used in the design module along with Group 2 and is shown in Figures 120-157.

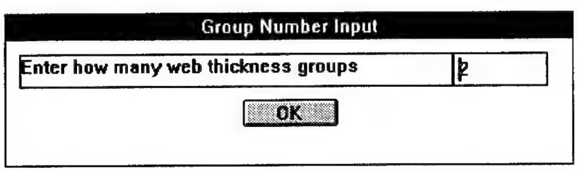


Figure 120. Number of web thickness groups

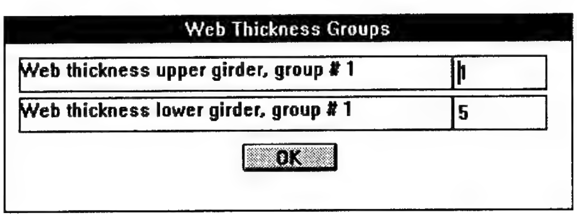


Figure 121. Web thickness Group 1 description

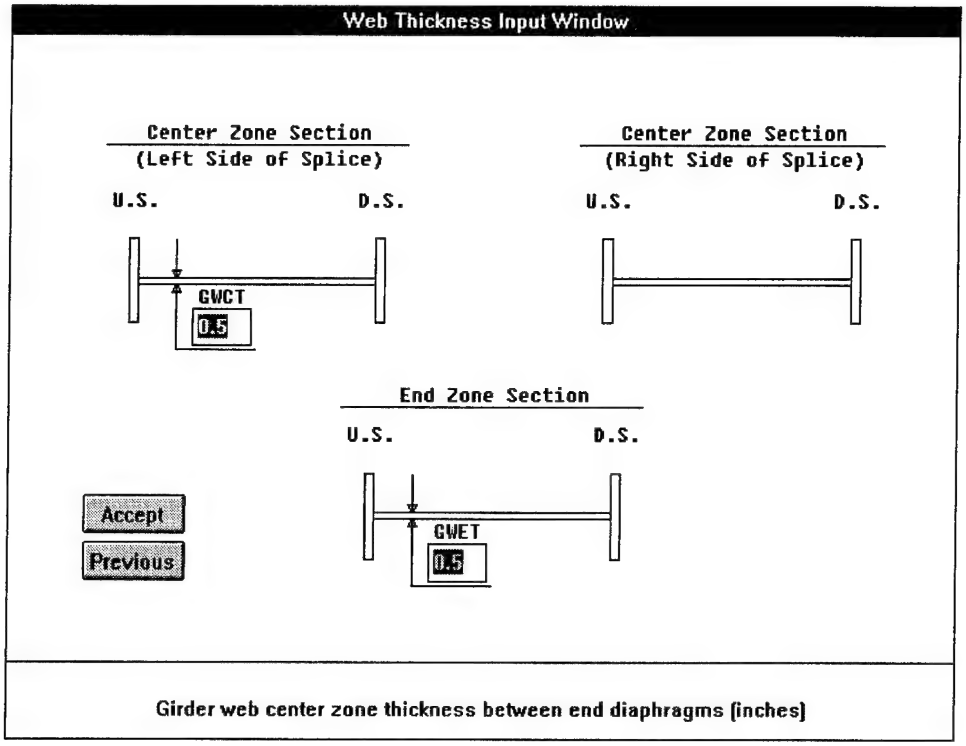


Figure 122. Web thicknesses, Group 1

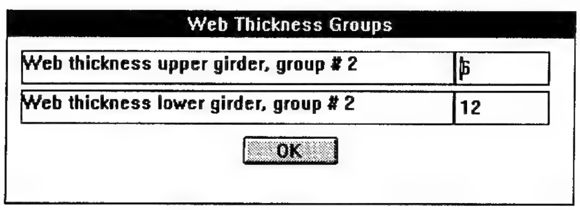


Figure 123. Web thickness Group 2 description

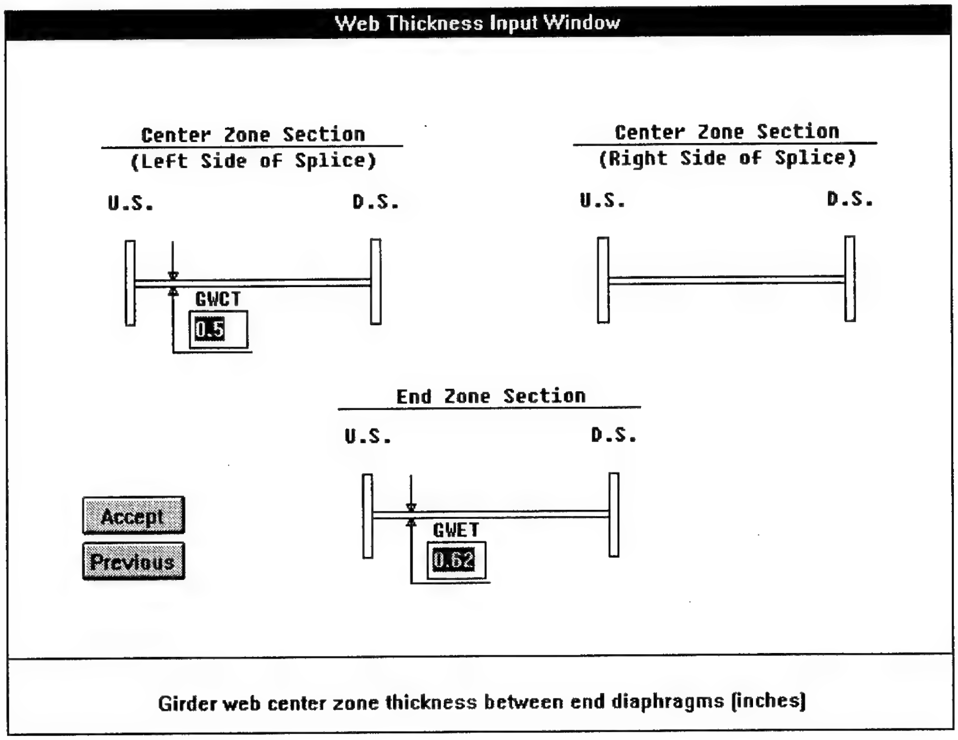


Figure 124. Web thicknesses, Group 2

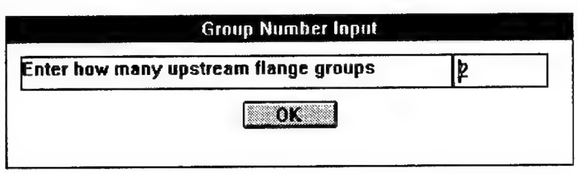


Figure 125. Number of flange groups

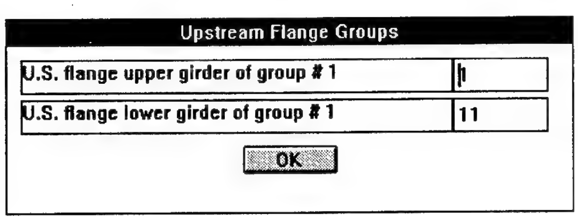


Figure 126. Upstream flange description, Group 1

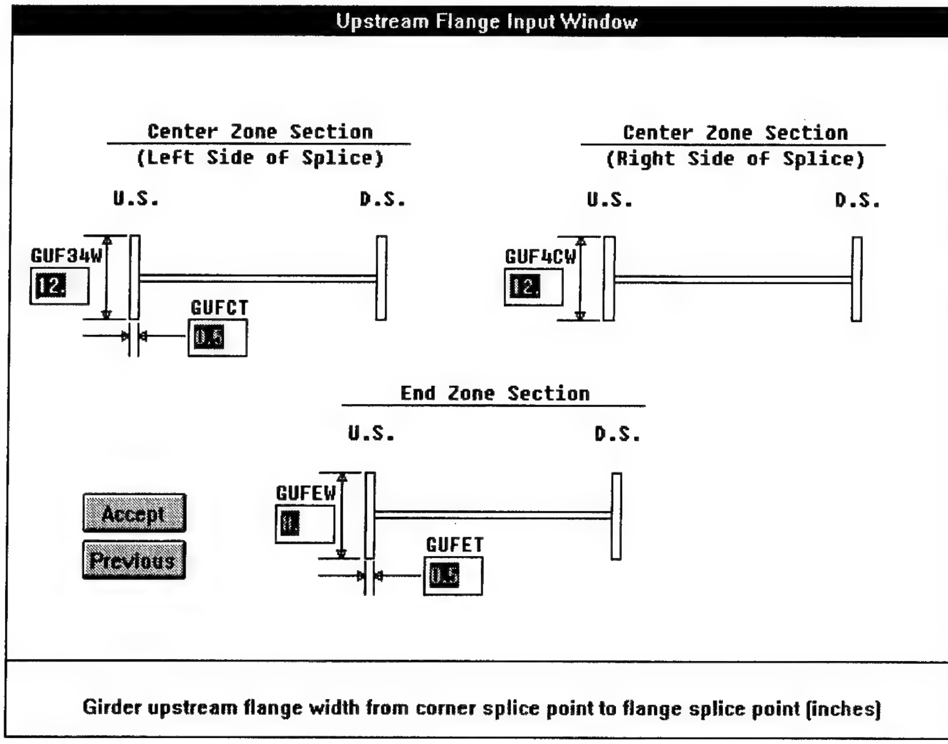


Figure 127. Upstream flange, Group 1

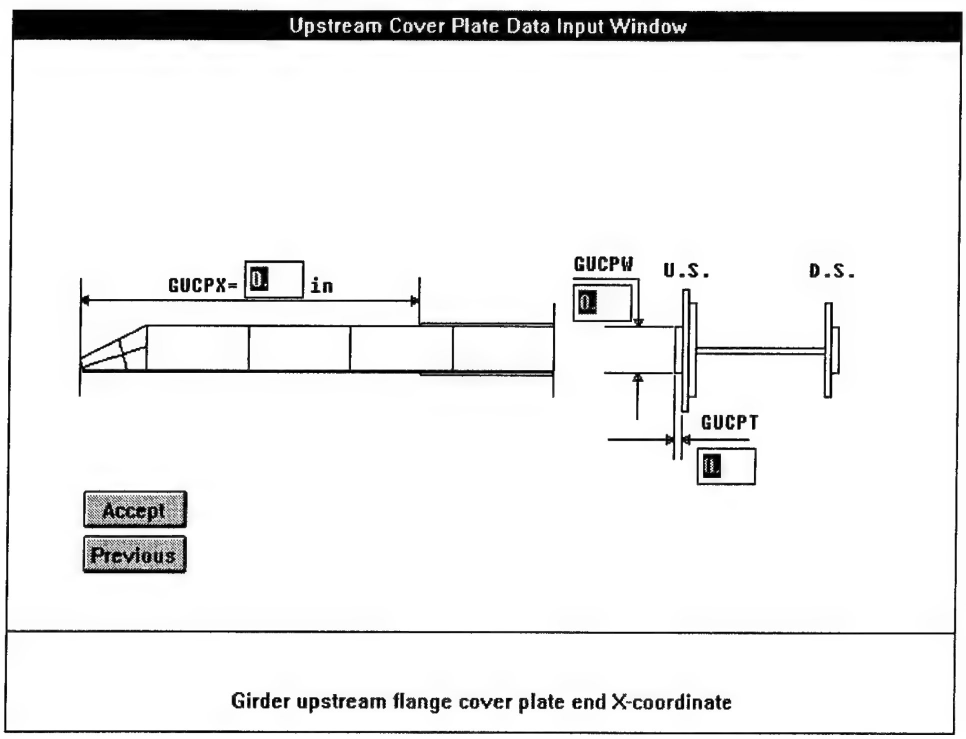


Figure 128. Upstream cover plate, Group 1

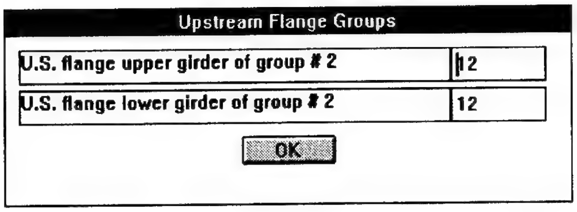


Figure 129. Upstream flange description, Group 2

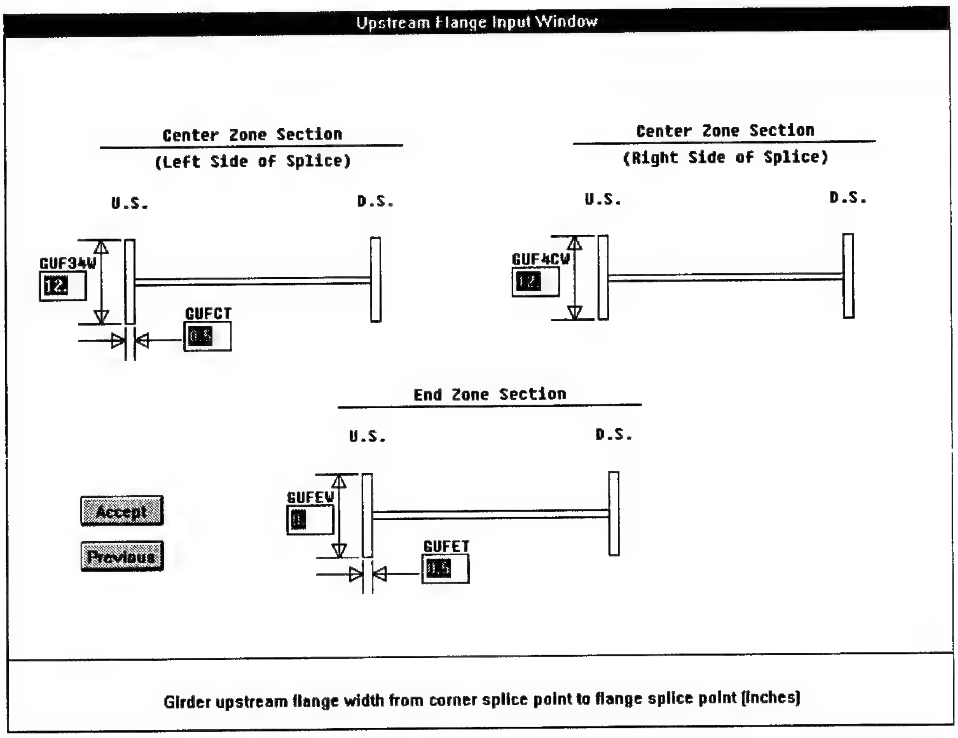


Figure 130. Upstream flange, Group 2

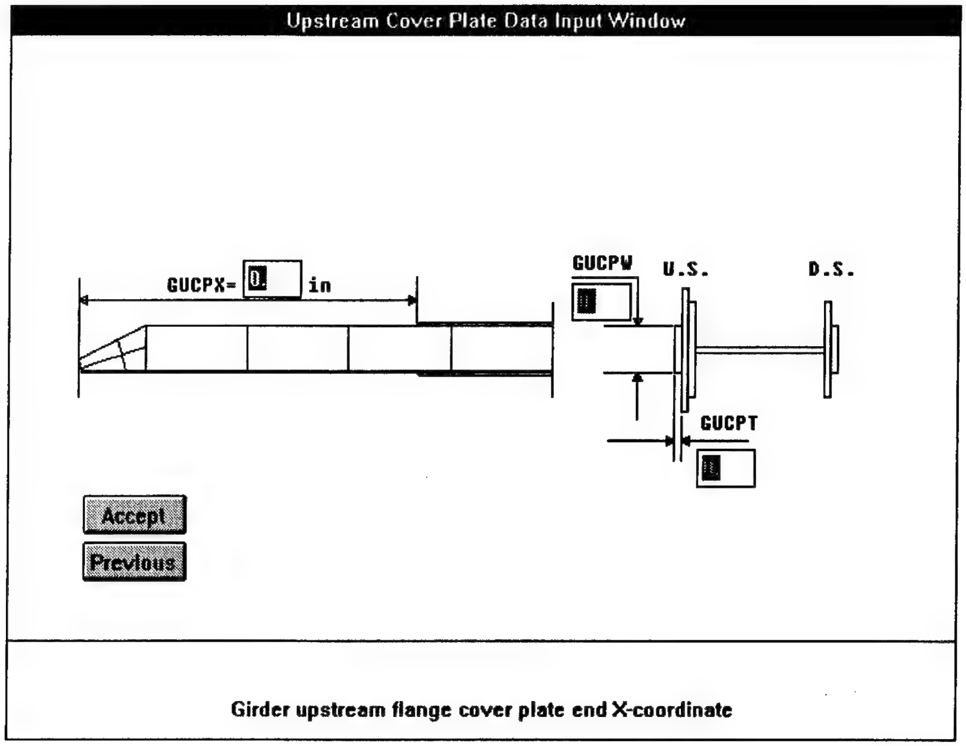


Figure 131. Upstream cover plate, Group 2

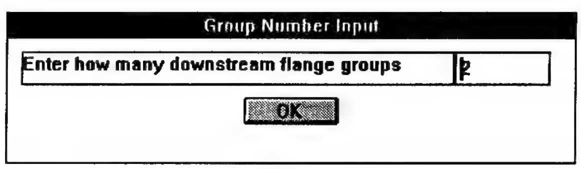


Figure 132. Number of downstream flanges

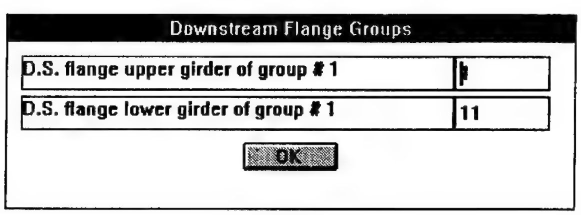


Figure 133. Downstream flange description, Group 1

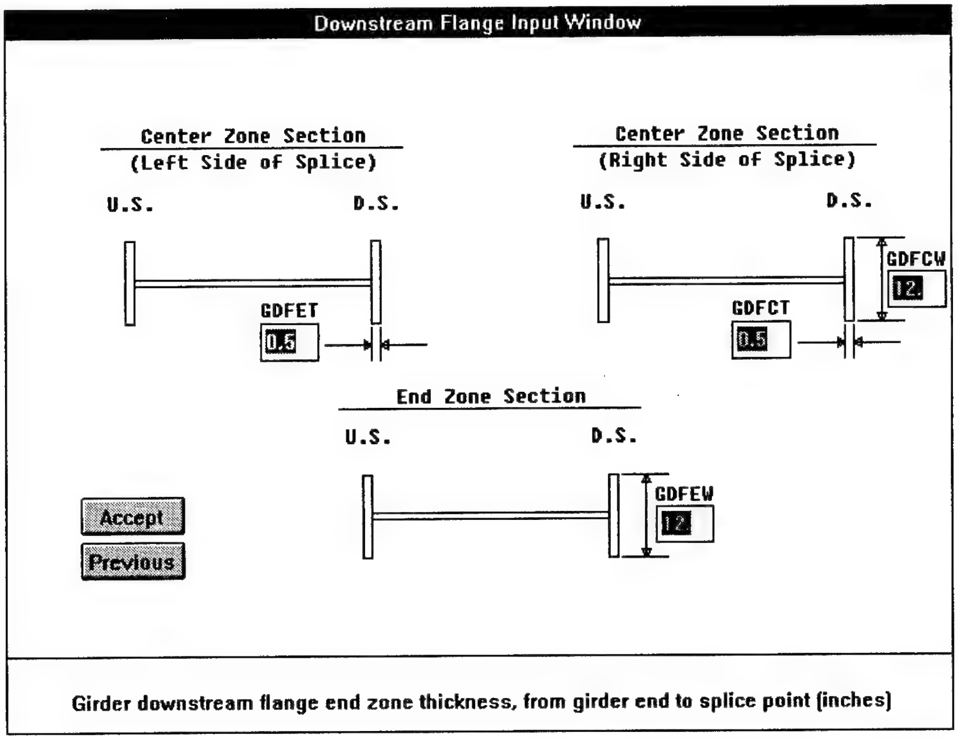


Figure 134. Downstream flanges, Group 1

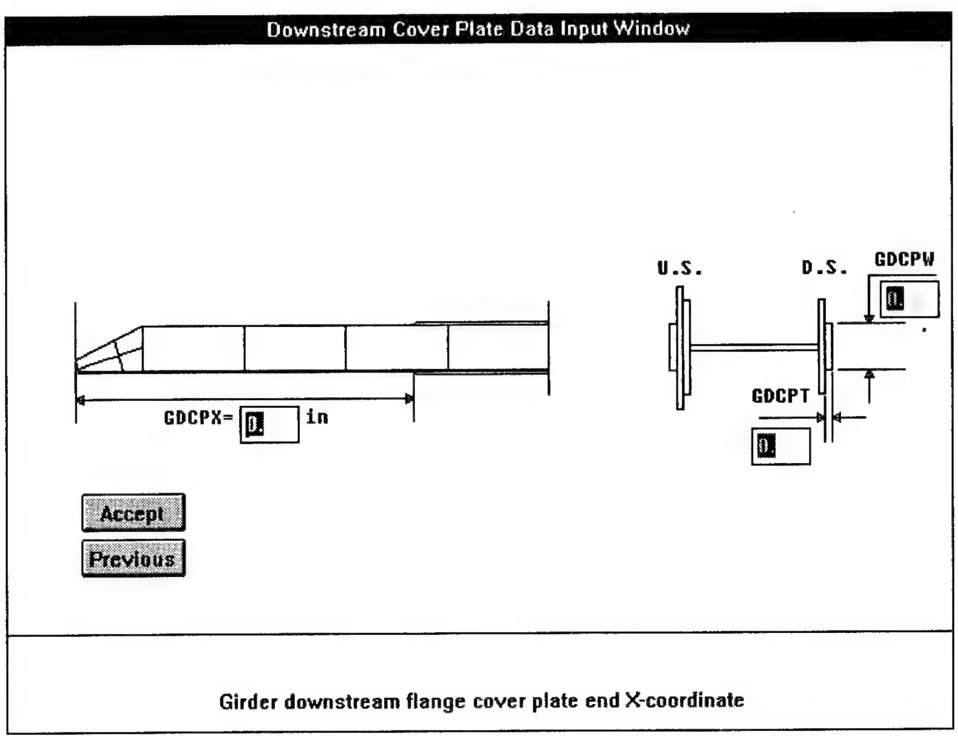


Figure 135. Downstream cover plate, Group 1

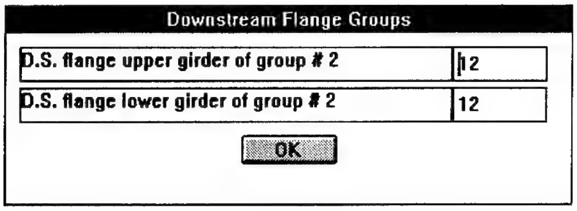


Figure 136. Downstream flange description, Group 2

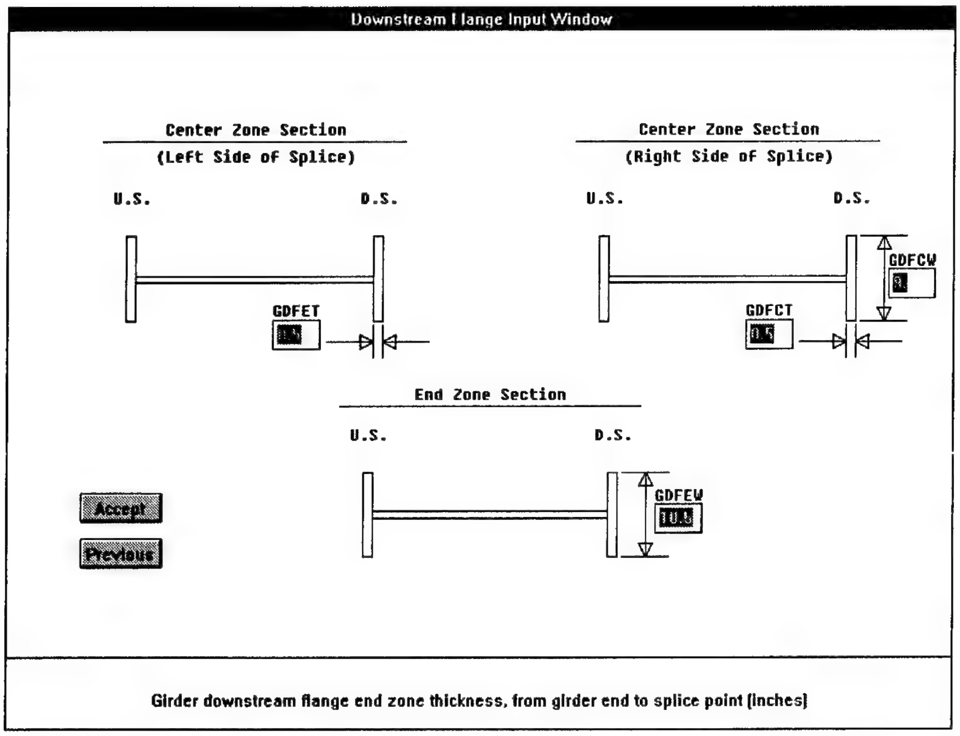


Figure 137. Downstream flanges, Group 2

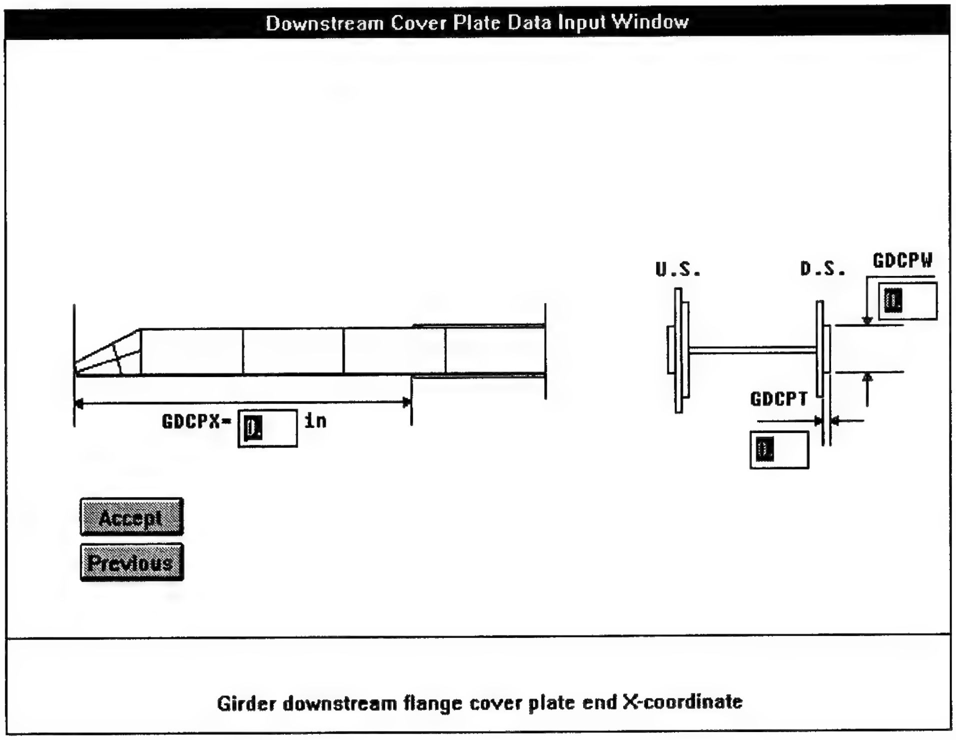


Figure 138. Downstream cover plate, Group 2

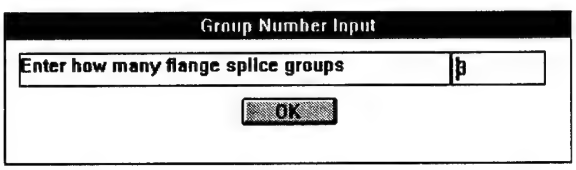


Figure 139. Number of splice point groups

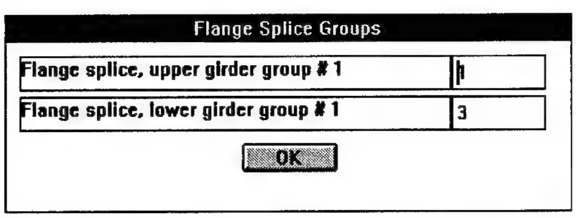


Figure 140. Splice point description, Group 1

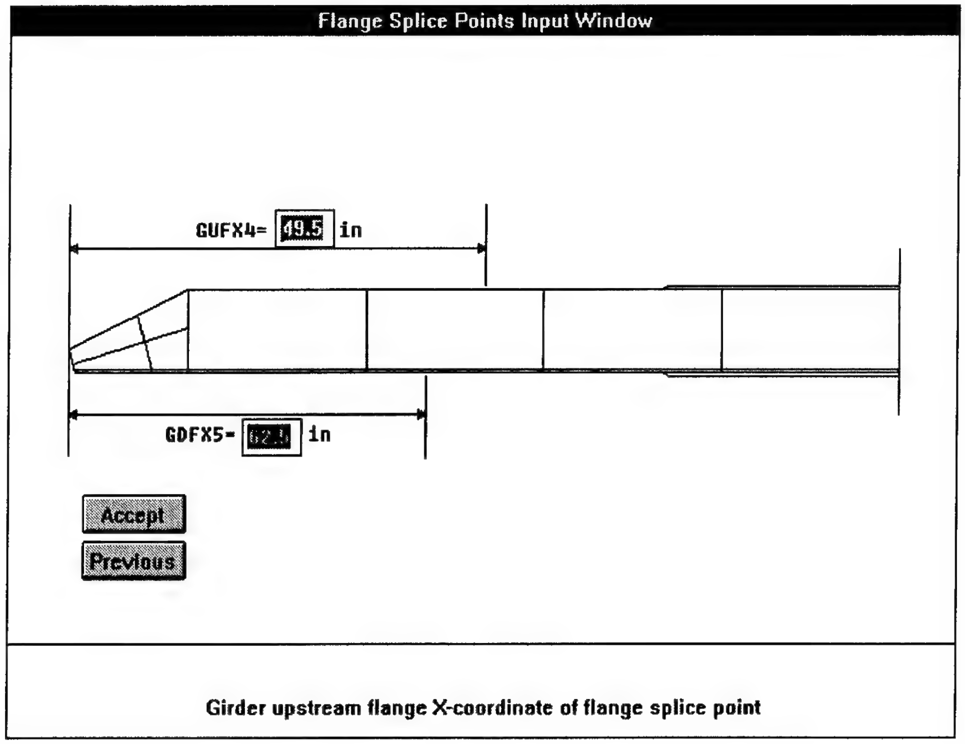


Figure 141. Splice points, Group 1

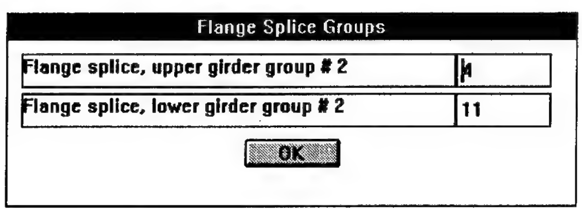


Figure 142. Splice point description, Group 2

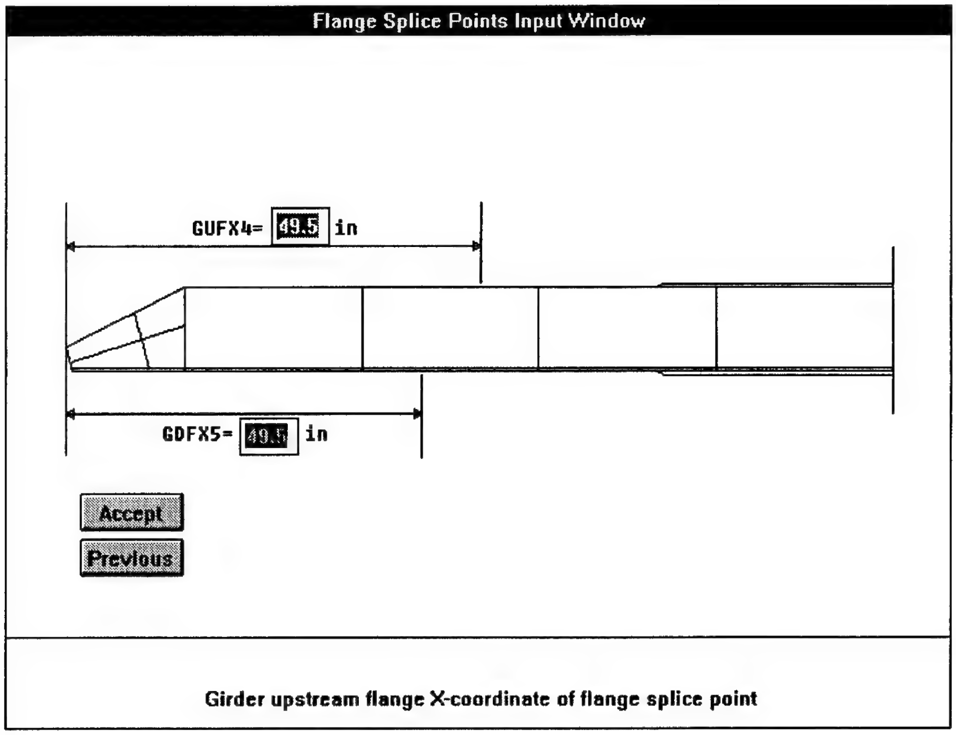


Figure 143. Splice points, Group 2

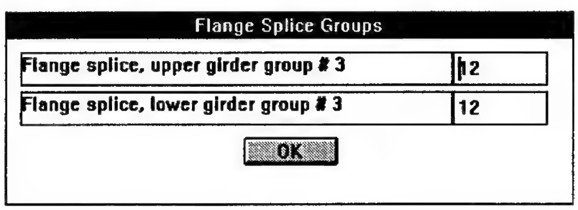


Figure 144. Splice point description, Group 3

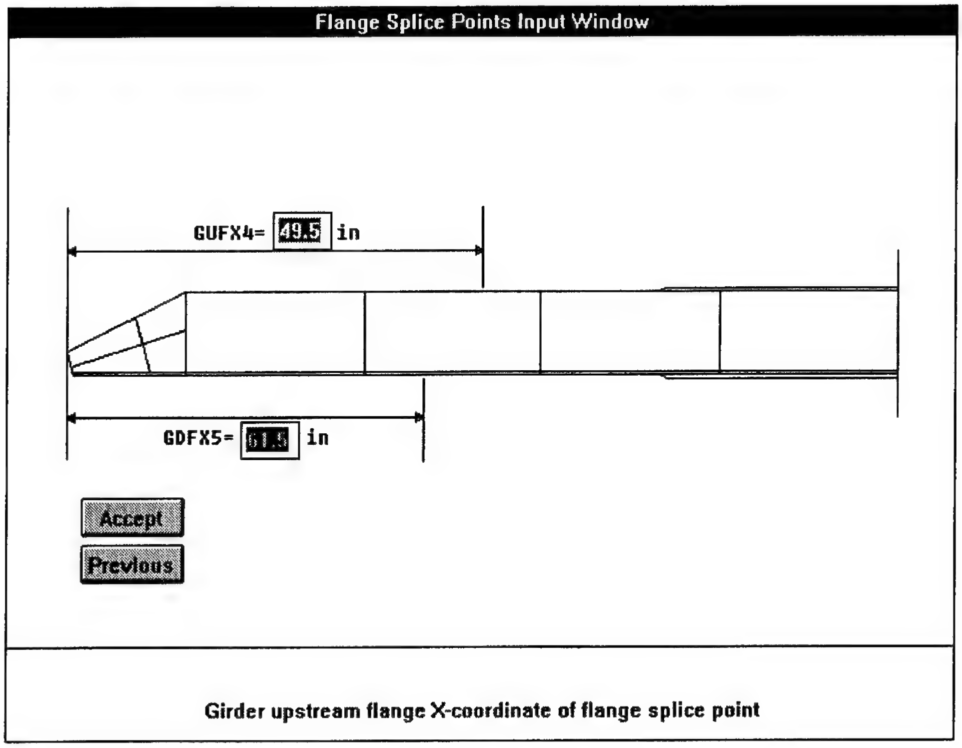


Figure 145. Splice points, Group 3

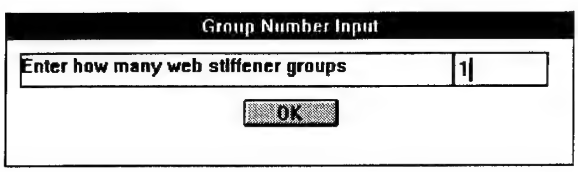


Figure 146. Number of web stiffener groups

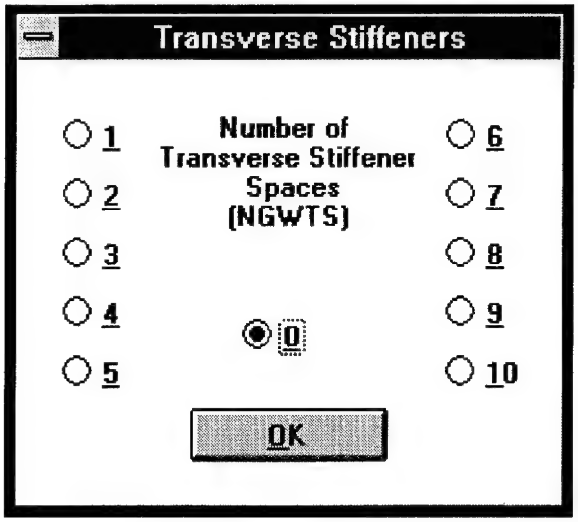


Figure 147. Number of transverse stiffeners

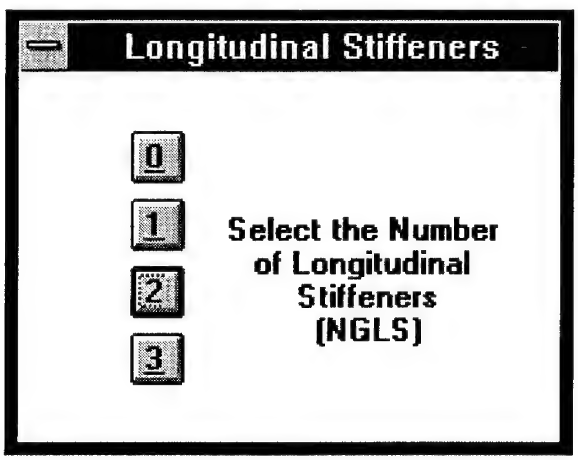


Figure 148. Number of longitudinal stiffeners

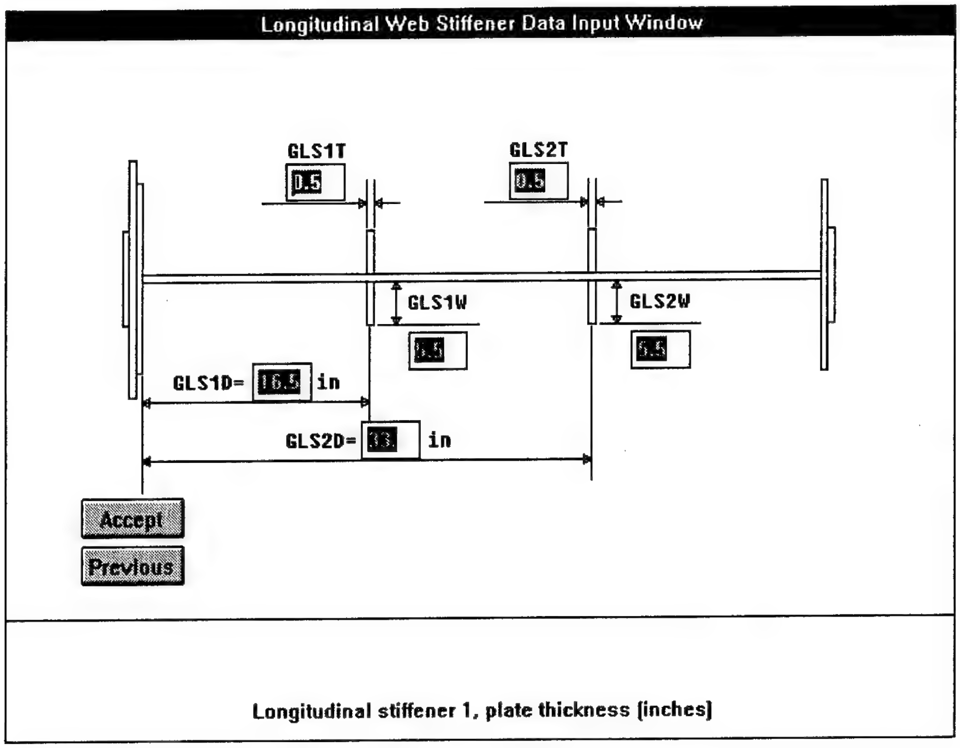


Figure 149. Longitudinal stiffeners

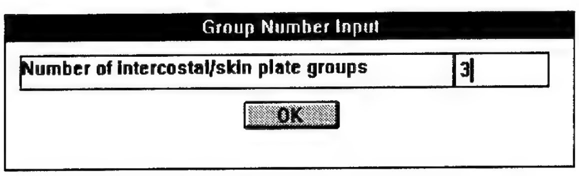


Figure 150. Number of intercostals/skin plate groups

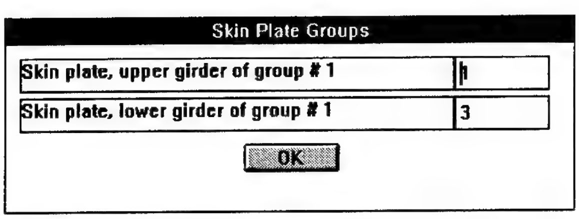


Figure 151. Intercostals/skin plate description, Group 1

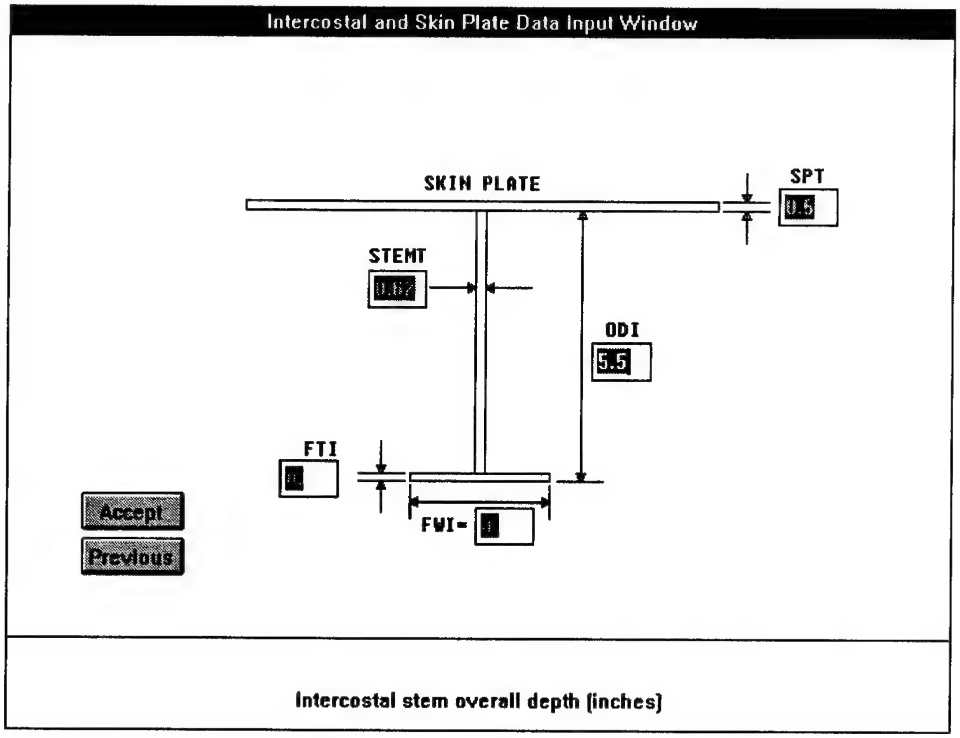


Figure 152. Intercostals/skin plate, Group 1

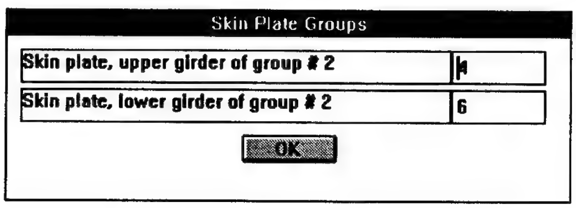


Figure 153. Intercostals/skin plate description, Group 2

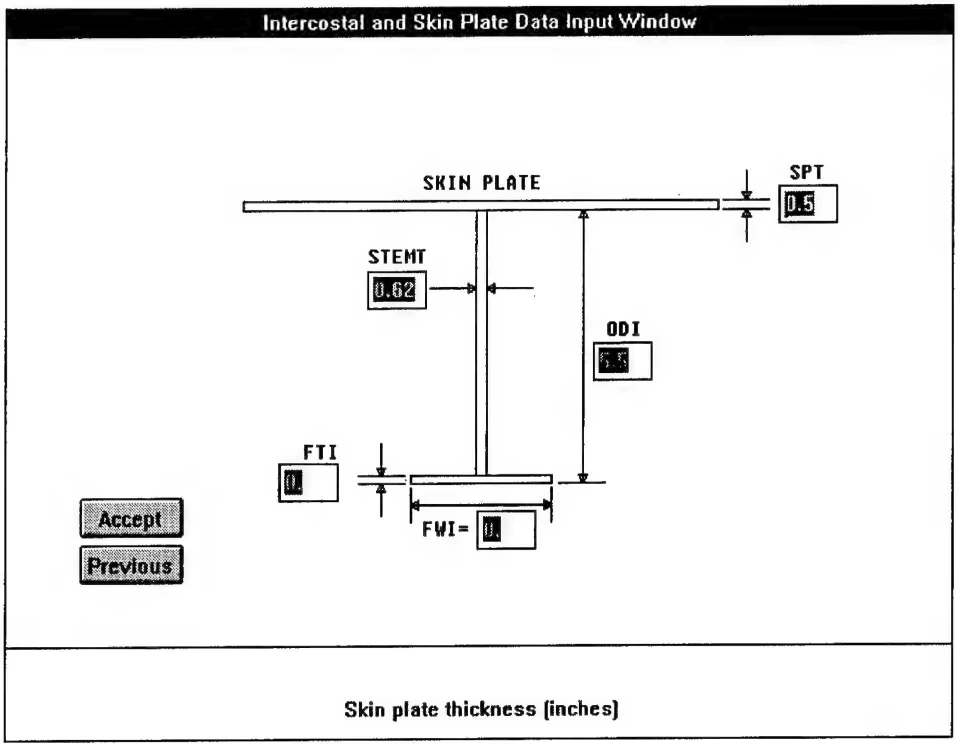


Figure 154. Intercostals/skin plate, Group 2

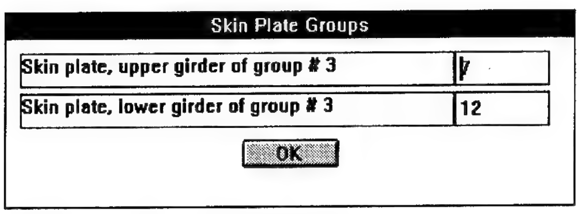


Figure 155. Intercostals/skin plate description, Group 3

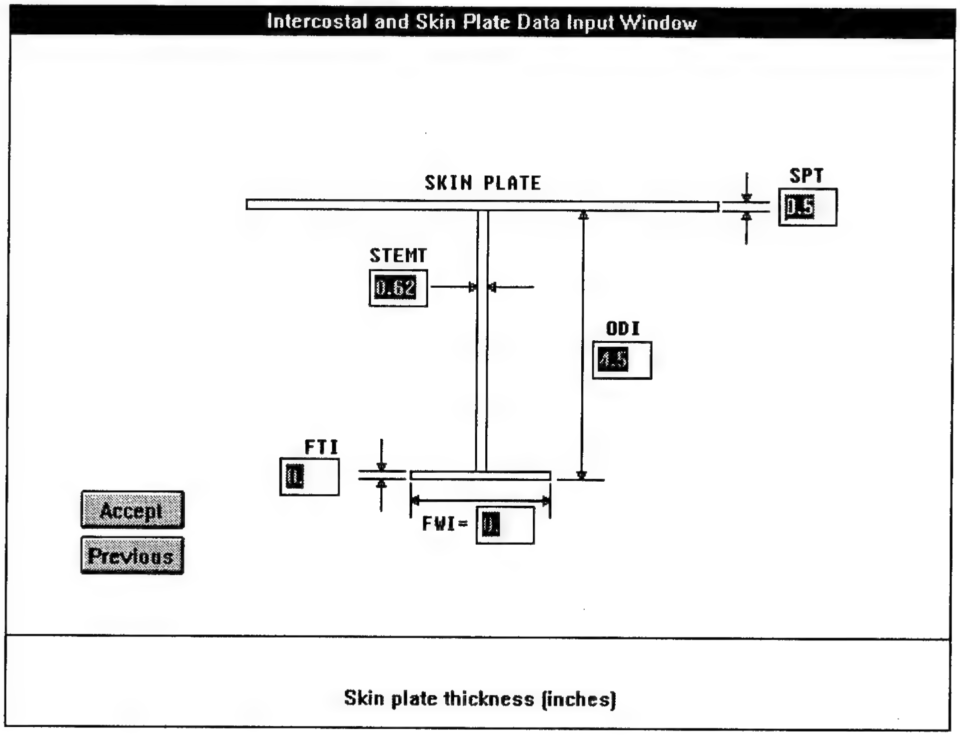


Figure 156. Intercostals/skin plate, Group 3

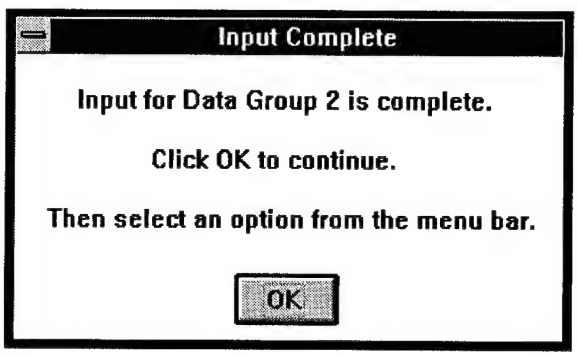


Figure 157. Input data Group 2 completed

INV module program execution

To run the INV module, press **Investigation** from the **Run Module** option (Figure 158). The windows sequence that will appear when INV module is executed follows in Figures 159-162.

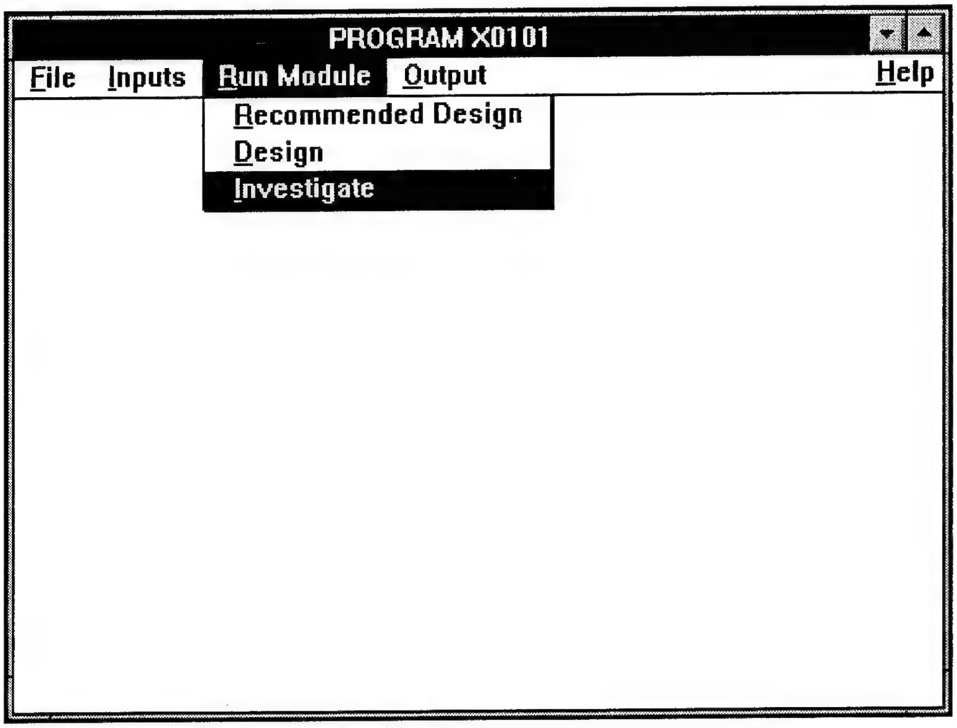


Figure 158. INV module execution

a. What design method do you prefer?

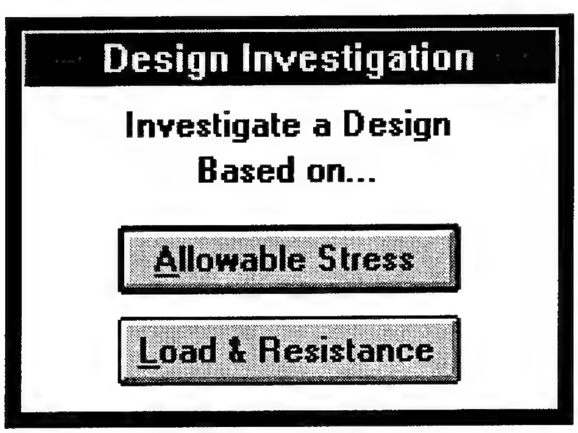


Figure 159. Design criteria for investigation

b. Output file.

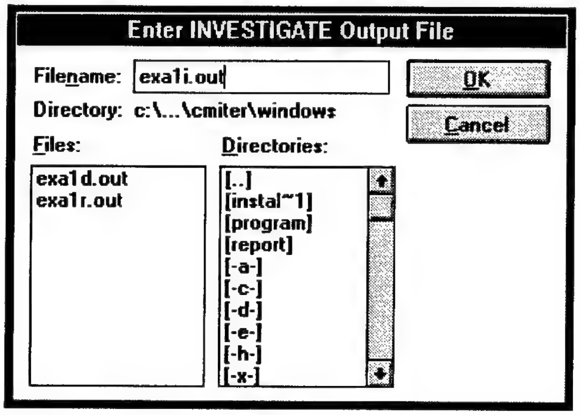


Figure 160. Output file

c. Compact or noncompact section.

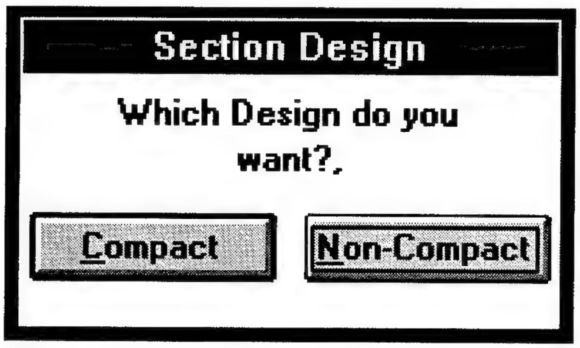


Figure 161. Plate girder investigation

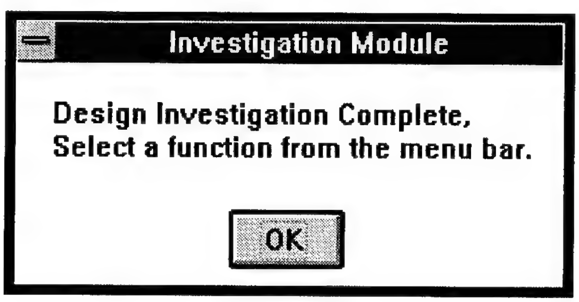


Figure 162. Completion of INV module

INV module output file

The investigation module output file (Figures 163-165) provides the user with the strength of the basic and detailed structural elements. The output file is organized in the following sections:

a. *Required input data.* All the data from the input file are reported in this section with a corresponding description.

b. *Skin plate investigation.* This section includes the panel dimensions and the stress, deflection, and stress range produced for the active load combinations. Also, it includes the flexural strength, fatigue strength, and limiting deflection.

   The bar graph shown in Figure 166 represents the stresses, deflections, and stress ranges acting on the skin plate. If any of the bars exceed the top horizontal line, the corresponding panel or panels are underdesigned. Plots can be seen individually by choosing the **Individual Plot** option. Users can move to the next or previous load combination by pressing **Next** or **Previous**, or return to the main menu by pressing **Menu**.

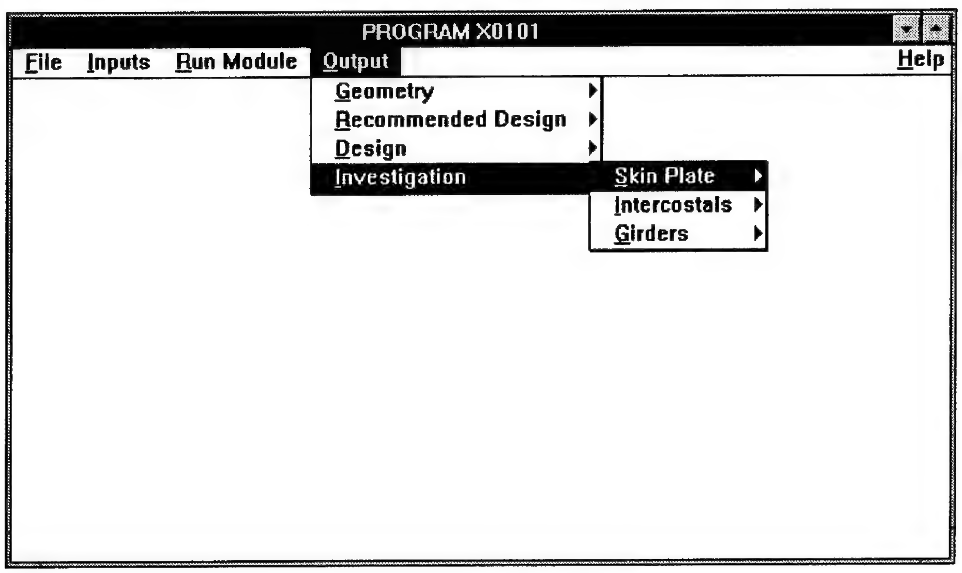


Figure 163. Output investigation options

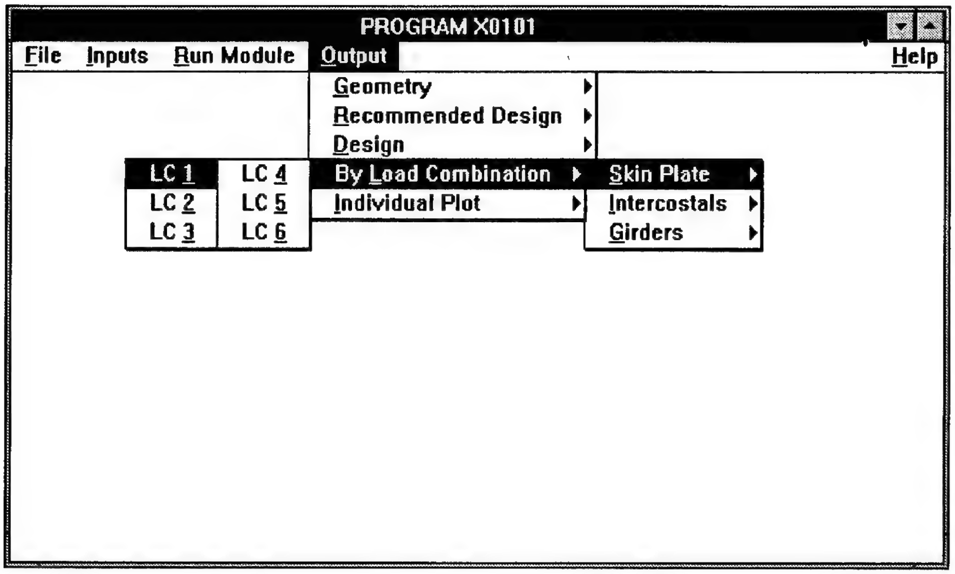


Figure 164. Skin plate investigation option

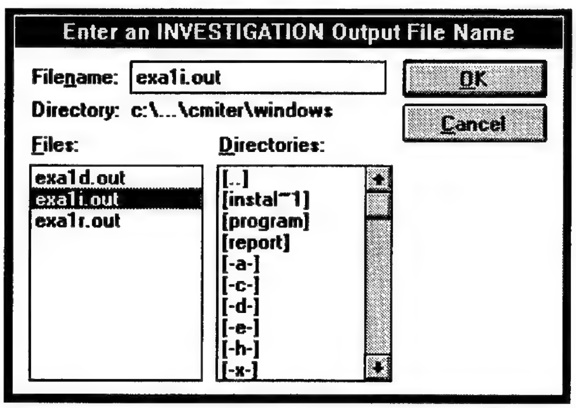


Figure 165. Output file

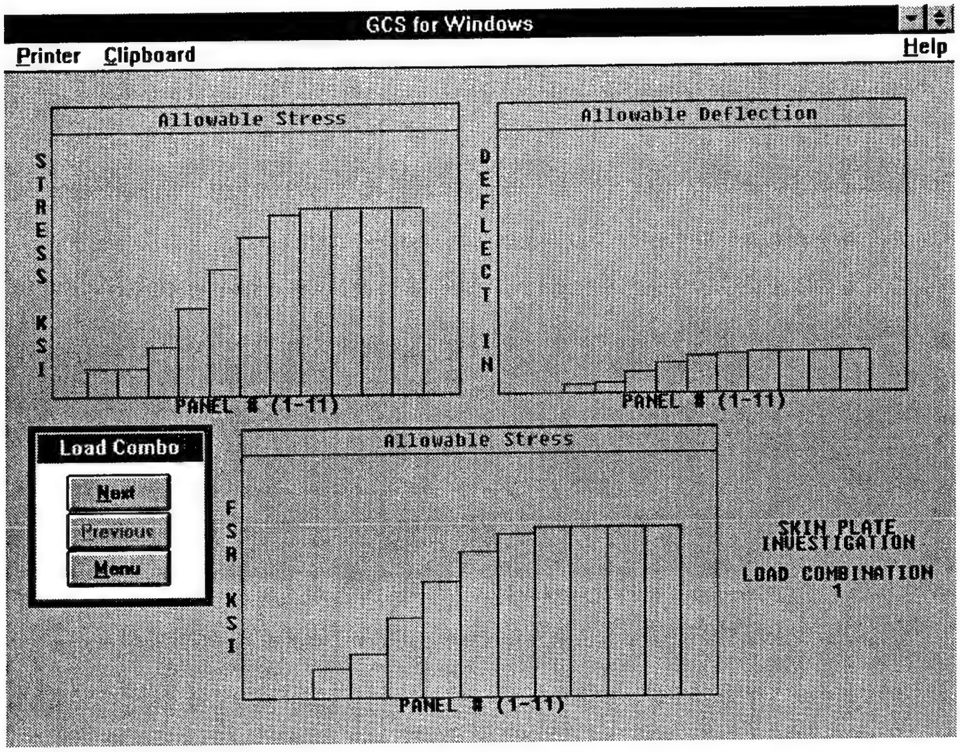


Figure 166. Skin plate investigation (LRFD)

c. *Intercostal investigation* (Figure 167). This section includes the intercostal dimensions, the moments produced for a fixed and pinned end condition for each of the active load combinations. The flexure strength is also included.

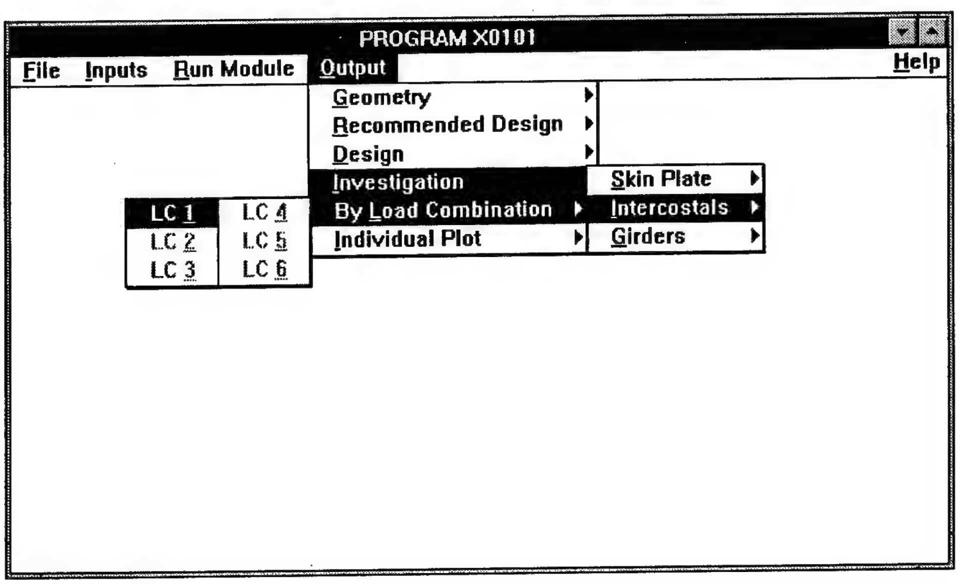


Figure 167. Intercostal investigation options

The bar graph in Figure 168 represents the magnitude of the moment and stress range for the cases of the intercostals fixed or simply supported. The horizontal line above each bar represents the strength of the section for the corresponding limit state. Plots can be seen individually by choosing the **Individual Plot** option. Users can move to the next or previous load combination by pressing **Next** or **Previous** or return to the main menu by pressing **Menu**.

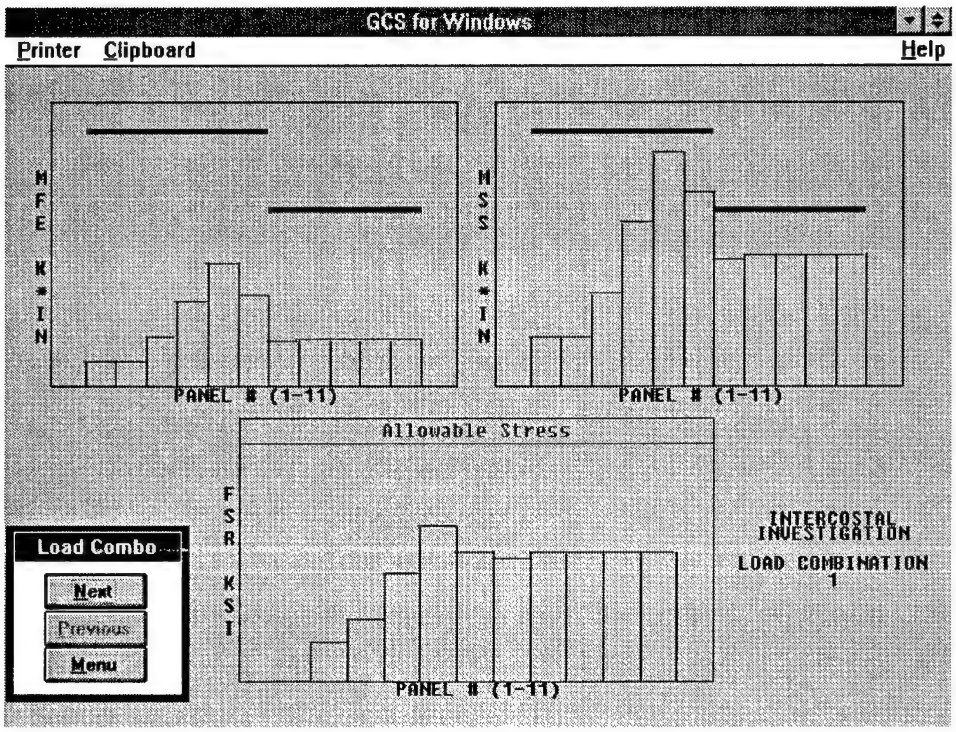


Figure 168. Intercostal investigation (LRFD)

d. *Girder investigation.* This section shows the dimensions, properties, acting forces, and strengths in the different sections of the girder (Figure 169). Girder investigation options are shown in Figure 170. Girder geometry and girder loads (LRFD) are shown in Figures 171 and 172, respectively.

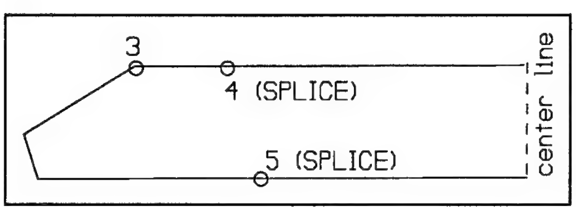


Figure 169. Plate girder investigation points

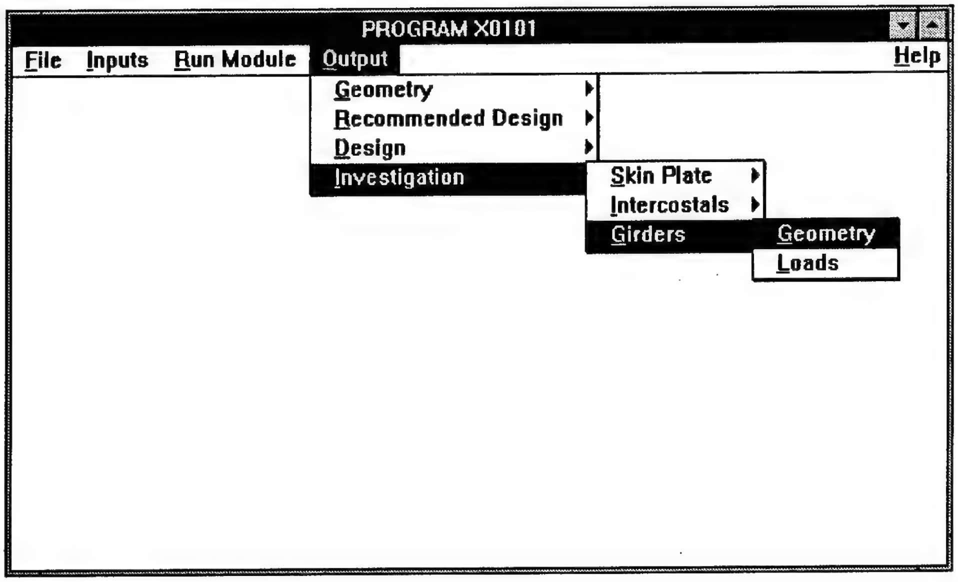


Figure 170. Girder investigation options

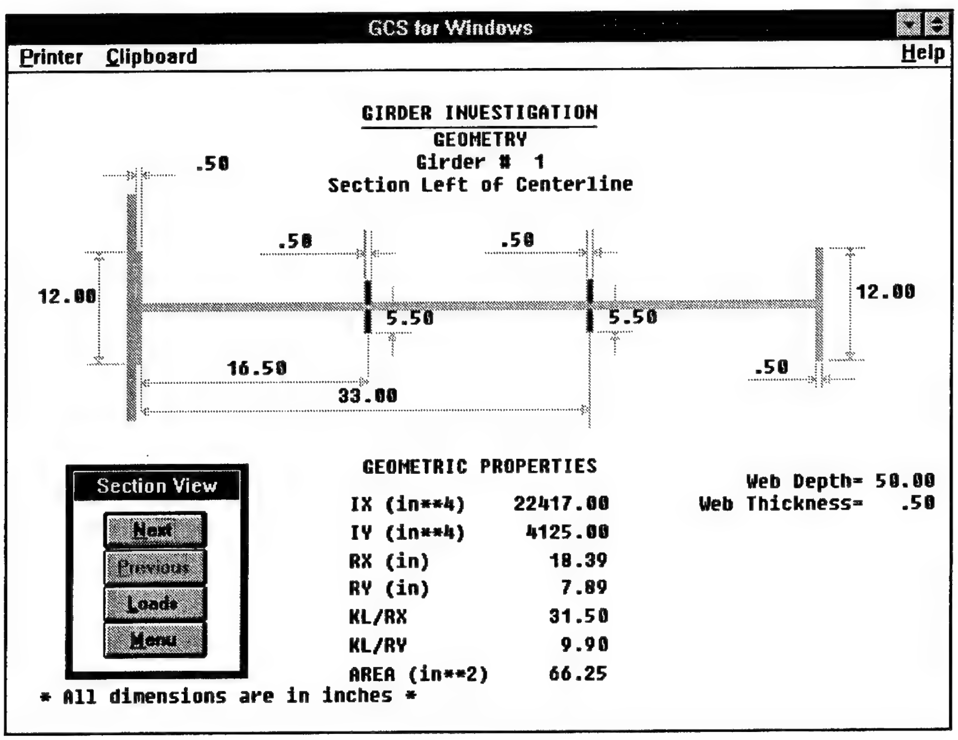


Figure 171. Girder geometry

Users can move to the next or previous girder by pressing **Next** or **Previous** or return to the main menu by pressing **Menu** (Figure 171).

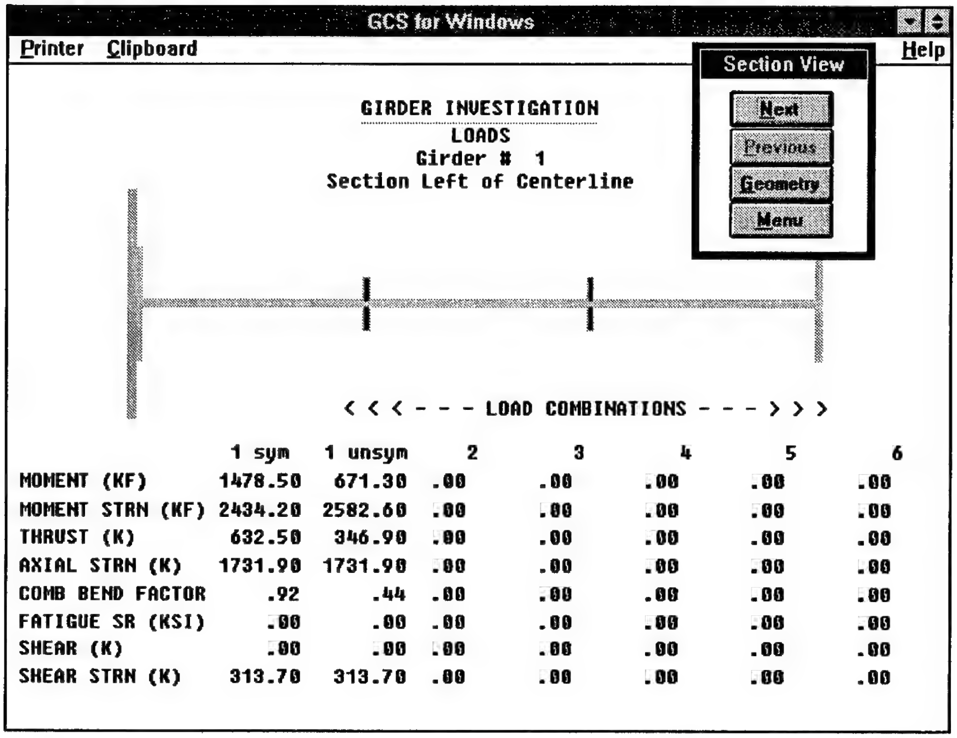


Figure 172. Girder loads (LRFD)

Users can move to the next or previous section by pressing **Next** or **Previous** or return to the main menu by pressing **Menu** (Figure 172). Red values indicate that the section is underdesigned for the particular limit state and and load combination.

e. *End diaphragm investigation.* This option presents a table with the stresses, deflections, and fatigue stress ranges acting on the end diaphragm due the active load combinations.

f. *Quoin post investigation.* This option presents the stresses at the points shown in Figure 15.

g. *Thrust diaphragm investigation.* This option presents a table with the stresses, deflections, and fatigue stress ranges acting on the thrust diaphragm due the active load combinations.

h. *Tapered end investigation.* This option presents a table with the stresses acting on tapered end section due the active load combinations.

i. *Diagonal investigation.* This option presents the parameters and the stresses acting on the diagonals for the active load combinations.

j. *Gate properties.* This option presents the weight and the center of gravity of the gate leaf.

6 Hand Calculations

Hand calculations were performed, and the results are presented in this chapter. The hand calculations were performed using the same values as those used in the investigation module input file, and the results are compared with the values of the investigation module output file (Riveros 1995). Figures 92, 93, and 155 show the example layout. Criteria to design each structural element are explained in Chapter 2.

Structural Analysis

Tables 3 and 4 show the individual loads and load combinations acting on the girders, and Tables 5 and 6 show the same data for the panels.

Table 3
Girder Unfactored Loads

Girder	*Hs* kips/ft^2	*Hs* kips/ft	*Ht* kips/ft^2	*Ht* kips/ft	*E* kips/ft^2	*E* kips/ft
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.13	0.078	0.156	0.0	0.0
3	0.31	1.870	0.078	0.429	0.043	0.26
4	0.68	4.12	0.078	0.468	0.063	0.38
5	1.06	6.36	0.078	0.468	0.079	0.47
6	1.25	7.10	0.078	0.429	0.092	0.50
7	1.42	7.79	0.078	0.351	0.101	0.45
8	1.73	7.71	0.078	0.312	0.119	0.48
9	1.935	7.75	0.078	0.312	0.141	0.56
10	1.935	7.75	0.078	0.312	0.156	0.62
11	1.935	7.75	0.078	0.312	0.169	0.67
12	1.935	5.805	0.078	0.234	0.180	0.54

Table 4
Girder Load Combinations

Girder No.	$1.4H_s + 1.0H_t$ kips/ft (Equation 7)	$1.2H_s + 1.0E$ kips/ft (Equation 10)
1	0.00	0.00
2	0.331	0.175
3	3.067	2.503
4	6.238	5.327
5	9.380	8.112
6	11.365	9.872
7	11.264	9.809
8	11.103	9.725
9	11.156	9.853
10	11.156	9.913
11	11.156	9.964
12	8.361	7.504

Table 5
Panel Unfactored Loads

Panel No.	H_s kips/ft^2	H_t kips/ft^2	E kips/ft^2
1	0.375	0.0	0.00
2	0.375	0.078	0.027
3	0.499	0.078	0.054
4	0.874	0.078	0.072
5	1.249	0.078	0.086
6	1.592	0.078	0.097
7	1.873	0.078	0.105
8	1.935	0.078	0.132
9	1.935	0.078	0.149
10	1.935	0.078	0.162
11	1.935	0.078	0.175

Table 6 Panel Load Combinations		
Panel No.	$1.4H_s + 1.0H_t$ kips/ft^2	$1.2H_s + 1.0E$ kips/ft^2
1	0.525	0.449
2	0.602	0.477
3	0.777	0.653
4	1.302	1.120
5	1.826	1.584
6	2.307	2.007
7	2.700	2.352
8	2.787	2.454
9	2.787	2.471
10	2.787	2.485
11	2.787	2.497

Skin Plate Design

The skin plate is designed as a fixed plate at the center line of the intercostals and the edges of the girder flanges. For panels 7-12 (Figure 92), horizontal girders are spaced 4 ft apart, and intercostals are spaced on 24-in. centers. With 6-in.-wide girder flanges, the plate dimensions are (see Chapter 2 for details):

$a = 36$ in.

$b = 24$ in.

$W_u = 2.787$ kips/ft^2 = 0.0194 ksi

$W = 1.935$ kips/ft^2 = 0.0134 ksi

$F_y = 36.0$ ksi

F_r = 21-ksi load condition 2, category C (Appendix K of AISC-LRFD (1986))

$\alpha = 0.9$

$\phi = 0.9$

where

W_u = skin plate factored load, ksi

W = skin plate unfactored load, ksi

F_y = skin plate yield strength, ksi

F_r = fatigue stress, ksi

α = reliability factor (see Chapter 2 for details)

ϕ = resistance factor (see Chapter 2 for details)

a. *Required-thickness-based yield limit state.* Equation 11 should be used to determine the skin plate thickness with $F = \alpha\phi F_y$, $W = W_u$, $\alpha = 0.9$, and $\phi = 0.9$.

$$t_{\min} = \sqrt{\frac{0.5Wb^2}{F\left[1 + 0.623\left(\frac{b}{a}\right)^6\right]}} \tag{68}$$

$$t_{\min} = \sqrt{\frac{0.5(0.0194)(24)^2}{29.16\left[1 + 0.623\left(\frac{24}{36}\right)^6\right]}} = 0.426 \text{ in.} \tag{69}$$

Use $t = 0.5$ in. (check with program to verify results).

Stress using $t = 0.5$ in. is:

$$\sigma = \frac{0.5W_ub^2}{t^2\left[1 + 0.623\left(\frac{b}{a}\right)^6\right]} \tag{70}$$

$$\sigma = \frac{(0.5)(0.0194)24^2}{0.5^2\left[1 + 0.623\left(\frac{24}{36}\right)^6\right]} = 21.14 \text{ ksi} \tag{71}$$

which is less than $\alpha\phi Fy = 29.16$ ksi. Therefore, the skin plate with a thickness of 0.5 in. is acceptable for the yield limit state.

b. *Deflection check.* Equation 12 should be used to calculate the deflection with $t = 0.5$ in. and $\delta_{all} = 0.4t$.

$$\delta = \frac{0.0284 W b^4}{\left[1 + 1.056\left(\frac{b}{a}\right)^5\right] E t^3} \tag{72}$$

$$\delta = \frac{0.0284(0.0134)(24)^4}{\left[1 + 1.056\left(\frac{24}{36}\right)^5\right](29000)\ (0.5)^3} \tag{73}$$

$$= 0.0306 \text{ in.}$$

which is less than $\delta_{all} = 0.4t = 0.2$ in. Therefore, the skin plate with a thickness of 0.5 in. is acceptable for deflection criteria.

c. *Minimum thickness required by fatigue.* Equation 11 should be used to determine the skin plate thickness with $F = F_r$, $W = W$.

$$t_{fat} = \sqrt{\frac{0.5\ (0.0134)\ (24)^2}{21\left[1 + 0.623\left(\frac{24}{36}\right)^6\right]}} = 0.417 \text{ in.} \tag{74}$$

The minimum thickness required by fatigue is 0.417 in.; use $t = 0.5$ in. (check with program to verify results). Fatigue stress using $t = 0.5$ in. is:

$$\sigma_f = \frac{0.5\ W b^2}{t^2\left[1 + 0.623\left(\frac{b}{a}\right)^6\right]} \tag{75}$$

$$\sigma_f = \frac{(0.5)\ (0.0134)\ (24)^2}{0.5^2\left[1 + 0.623\left(\frac{24}{36}\right)^6\right]} = 14.68 \text{ ksi} \tag{76}$$

which is less than $F_r = 21.0$ ksi. Therefore, the skin plate with a thickness of 0.5 in. is acceptable for fatigue criteria.

Note that the skin plate with a thickness of 0.5 in. is also acceptable for yield limit state, deflection, and fatigue. Therefore, the skin plate with a thickness of 0.5 in. is acceptable.

Intercostal Design

For this design example, the intercostals in panels 7 through 11 (Figures 92 and 93) are assumed to have a pin-support condition and a plate section (Figures 7 and 8). The intercostals are spaced on 24.0-in. centers and have a 48-in.-long girder center line spacing (G = 48.0 in.). The load is applied as a trapezoidal distribution as shown in Figure 8 (see Chapter 2 for details). The top and bottom girders have flanges with $F/2$ = 6.0 in., S = 36 in., a = 12 in., and b = 12 in. (see Figure 8 for details). The required factored moment capacity for the intercostal subjected to the trapezoidal load is M_u = 97.549 kip-in. (SBM in Figure 8, check with program to verify).

The effective width of the skin plate is determined assuming that the skin plate is an unstiffened, noncompact element under compression (AISC 1986). The width-to-thickness ratio to satisfy this requirement is:

$$\lambda = \frac{b}{2t_f} \leq \lambda_r = \frac{95}{\sqrt{F_y}} \tag{77}$$

The effective width b_e of a 0.5-in.-thick plate is then

$$b_e = \frac{2t_f(95)}{\sqrt{F_y}} = \frac{2\ (0.5)\ (95)}{\sqrt{36}} = 15.83\ in. \tag{78}$$

The chosen intercostal section (Figure 155) is a plate section with a 4.5-in. stem and 0.625-in. thickness that produces a T-section in combination with the effective width (15.83 in.) of the skin plate (t = 0.5 in.). In accordance with EM 1110-2-2105, the stem satisfies noncompact requirements.

$$\frac{d}{t} = \frac{6.0}{0.75} = 8.0 < \frac{127}{\sqrt{F_y}} = 21.2 \tag{79}$$

In accordance with Chapter 2, the nominal strength $M_n = M_y$, $\lambda < \lambda_r$, and the compression flange has continuous lateral support ($L_b = 0$). The section has an area of 10.73 in.^{2}, a moment of inertia I_x of 17.91 in.^{4}, a minimum section module S_x = 4.37 in.^{3}, and a yield moment of M_y = 157.5 kip-in. The design strength is:

$$\alpha\Phi M_y = (0.9)\ (0.9)\ 157.2 = 127.3\ kip\text{-}in.$$

which exceeds the required M_u = 97.545 kip-in. Therefore, a 4.5- by 0.625-in. stem is acceptable.

Girder Design

This example applies to the design of the critical horizontal girder. The required cross section at the end diaphragm and center span is selected (girders 6-11 of Figure 93). The required leaf span from the quoin block to miter block is 48.25 ft (579.0 in.), with a 50-in. web depth (Figure 173). Uniform load and reactions are shown in Figure 9. The girder is subject to reverse bending. However, at the center span, the upstream flange is in compression, whereas it is in tension in the end diaphragm section. The upstream flange is fully laterally supported by the skin plate. The downstream flange is braced against lateral displacement and twist of the cross section by intermediate diaphragms every 120 in. Transverse stiffeners are not required in this section.

a. *Width-to-thickness ratios.* For this example, the section is proportioned with the following width-to-thickness ratios to satisfy the noncompact section requirements:

For girder flanges (Table 1),

$$\lambda_r \leq \frac{106}{\sqrt{F_y - 16.5}} = \frac{106}{4.42} = 24 \tag{80}$$

Girder webs should be proportioned using requirements of uniformly compressed stiffened elements (Table 1 and AISC 1986).

$$\lambda_r \leq \frac{253}{\sqrt{F_y}} = \frac{253}{6} = 42.2 \tag{81}$$

b. *Design loading.* For this girder, the controlling load combination is given by Equation 7. Based on Equation 7, the factored distributed load is equal to 11.37 kips/ft or 0.948 kips/in. (W in Figure 9). This loading produces an axial compressive resultant load equal to 867.0 kips ($P_1 + P_2$ in Figure 9), and a moment at center span equal to 1,372.7 kip-ft, with a moment at the end diaphragm equal to M_n = 900.4 kip-ft. The maximum shear load is equal to 274.2 kips (N in Figure 9).

c. *Cross-section properties.* The section is composed of 12- by 0.5-in. downstream and upstream flanges and a 50- by 0.5-in. web with 5.5- by 0.5-in. longitudinal stiffeners located as shown in Figure 173. The effective width of the skin plate adjacent to each edge of the upstream girder flange is based on a $\dfrac{106}{\sqrt{F_y - 16.5}}$ width-to-thickness ratio as needed to satisfy noncompact section requirements. The girder has the following properties:

$I_x = 22{,}329.4 \text{ in.}^4$

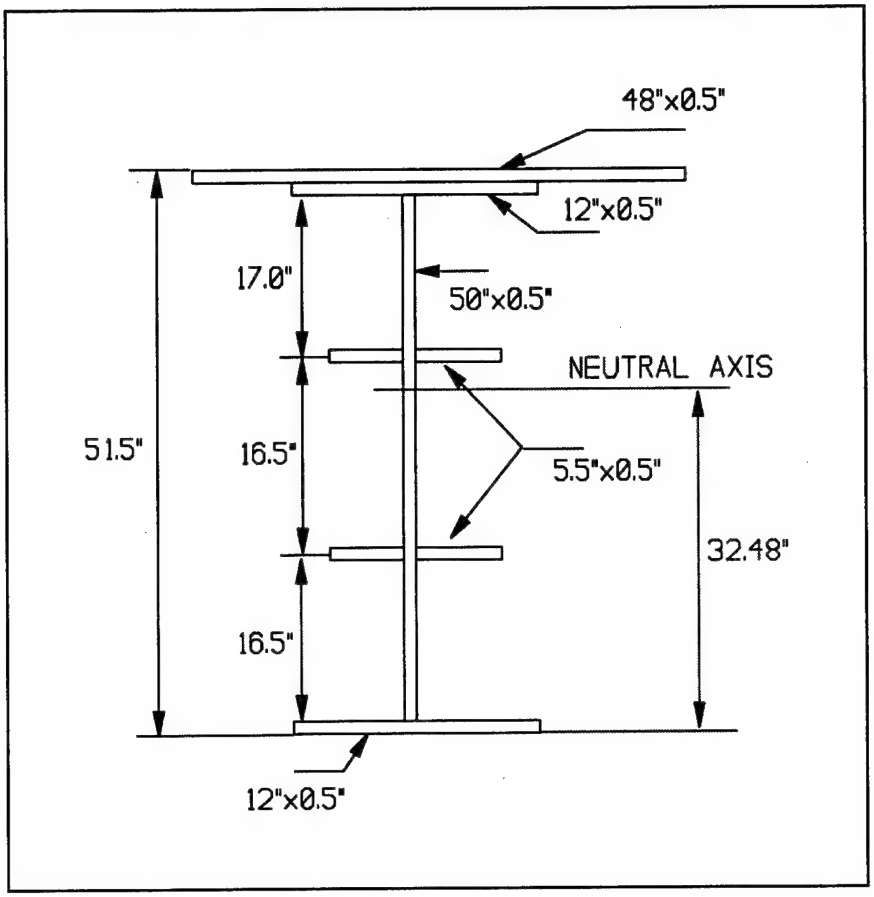


Figure 173. Girder cross section

$r_x = 18.387$ in.

$r_y = 5.785$ in.

$S_{x1} = 1{,}173.97$ in.^{3}

$S_{x2} = 687.47$ in.^{3}

$Z_x = 1{,}058.02$ in.^{3}

$y_c = 19.02$ in.

$A_g = 66.0$ in.^{2}

d. Noncompact section check. The following calculations show that the section is noncompact. With two lines of longitudinal stiffeners located as shown in Figure 175, the maximum clear distance of the web is $d = 17.0$ in. The width-to-thickness ratio for the web is

$$\lambda = \frac{d}{t} = \frac{17.0}{0.5} = 34.0 \qquad (82)$$

which is less than λ_r of Table 1. Therefore, the web is compact. For the upstream flange, the width-to-thickness ratio including the skin plate is

$$\lambda = \frac{b}{2t} = \frac{12}{2\ (1.0)} = 6.0 < \lambda_p \qquad (83)$$

which is less than λ_p of Table 1. Therefore, the upstream flange is compact. For the downstream flange, the width-to-thickness ratio is

$$\lambda = \frac{b}{2t} = \frac{12}{2\ (0.5)} = 12.0 \qquad (84)$$

which is greater than λ_p and less than λ_r of Table 1. Therefore, the downstream flange is noncompact. Since the plate girder section requires that just one element be noncompact, the plate girder section is noncompact.

e. *Web shear.* The girder web will be checked for the maximum shear V_u = 274.4 kips (see Chapter 2, Equations 42 through 45, for design criteria), for

$$\frac{h}{t_w} < \frac{187}{\sqrt{\dfrac{k}{F_{yw}}}},\ V_n = 0.6F_{yw}A_w \qquad (85)$$

where

$$k = 5 + \frac{5}{\left(\dfrac{a}{h}\right)^2} \qquad (86)$$

unless a/h exceeds 3.0 or $[260/(h/t_w)]^2$, in which case $k = 5$. With a = 120 in. (intermediate diaphragm spacing) and h = 17.0 in. (web maximum clear depth):

$$\frac{a}{h} = \frac{120}{17.0} = 7.05 > 3\ ;\ k = 5 \qquad (87)$$

$$\frac{h}{t_w} = \frac{17.0}{0.5} = 34.0 < 187\sqrt{\frac{5}{36}} = 69.7 \qquad (88)$$

$$V_n = 0.6\ (36)\ (25) = 540\ kips \qquad (89)$$

$$\alpha\Phi V_n = (0.9)\ (0.9)\ (540) = 437.4\ kips \tag{90}$$

which is greater than $V_u = 274.2$ kips. Therefore, the section is acceptable for shear.

f. Combined forces. The horizontal girder is considered a singly symmetrical prismatic member subjected to axial force and flexure about its major axis (see Chapter 2 for design criteria).

(1) Determine axial strength (Equations 15 through 17).

(a) Slenderness ratios

$$\frac{Kl_x}{r_x} = \frac{1.0\ (579)}{18.39} = 31.50 \text{ controls} \tag{91}$$

$$\frac{Kl_y}{r_y} = \frac{0.65\ (120)}{5.79} = 13.47 \tag{92}$$

(b) Calculate the critical stress F_{cr},

$$\lambda_c = \frac{Kl}{r\pi}\sqrt{\frac{F_y}{E}} = \frac{31.5}{\pi}\sqrt{\frac{36}{29{,}000}} = 0.353 \tag{93}$$

$$F_{cr} = (0.658^{\lambda^2 c})\ F_y = (0.658^{0.125})\ 36.0 = 34.17 \text{ kips} \tag{94}$$

(c) Calculate the axial strength

$$P_n = A_g F_{cr} \tag{95}$$

$$P_n = (66.0)\ 34.17 = 2{,}255.22 \text{ kips} \tag{96}$$

$$\alpha\phi P_n = (0.9)\ (0.85)\ 2{,}255.22 = 1{,}725.11 \text{ kips} \tag{97}$$

which is greater than $P_u = 867.0$ kips. Therefore, the section is acceptable for compression load.

(2) Determine whether Equation 38 or 39 should be used in members subject to bending and axial force for center-line section with $P_u = 867.13$ kips, $\phi_c = 0.85$, and $\alpha = 0.9$:

$$\frac{P_u}{\alpha\Phi_c P_n} = \frac{867.13}{(0.9)\ (0.85)\ 2{,}255.22} = 0.503 \tag{98}$$

which is greater than 0.2. Therefore, Equation 38 should be used.

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left(\frac{M_{ux}}{\phi_{bM_{nx}}} + \frac{M_{uy}}{\phi_b M_{ny}}\right) < 1.0 \tag{99}$$

$$M_{uy} = 0 \tag{100}$$

(3) Determine the moment magnifier to be used in Equations 40 and 41:

$$B_1 = \frac{c_m}{\left(1 - \dfrac{P_u}{P_e}\right)} \geq 1.0 \tag{101}$$

$$P_e = \frac{A_g F_y}{\lambda_c^2} = \frac{(66.0)\ (36)}{0.125} = 19{,}037.97 \tag{102}$$

Substituting the values above with $C_m = 1.0$ in Equation 40, the moment magnifier is

$$B_1 = \frac{1.0}{\left(1.0 - \dfrac{867.1}{19{,}037.97}\right)} = 1.05 \tag{103}$$

(4) Determine the maximum acting moment at girder center line:

$$M_{ux} = B_1 M_{nt} + B_2 M_u \tag{104}$$

$$M_u = 0 \tag{105}$$

$$\begin{aligned} M_{ux_{CL}} &= B_1 M_{nt} = 1.05\ (16{,}472.24) \\ &= 17{,}295.49 \text{ kip-in.} \end{aligned} \tag{106}$$

(5) Determine flexure strength, center-line section. For a noncompact section with the compression flange fully laterally supported (center-line section), the flexure strength is the plastic moment (Equation 18).

$$\begin{aligned} M_n &= M_p = F_y Z = (36)\ (1{,}058.02) \\ &= 38{,}088.72 \text{ kip-in.} \end{aligned} \tag{107}$$

$$\alpha\phi M_n = (0.9)\ (0.9)\ 38{,}088.72$$
$$= 30{,}851.86 \text{ kip-in.} \tag{108}$$

which is greater than M_{uxCL} = 17,295.49 kip-in. Therefore, the section is acceptable for bending.

(6) Determine if the section is acceptable for combining loads (axial and flexure) by substituting the values above into Equation 38:

$$0.51 + \frac{8}{9}\left[\frac{17{,}295.49}{(0.9)\ (0.9)\ (38{,}088.72)}\right] = 1.00 \tag{109}$$

Since the value is 1.0, the center-line section is acceptable.

(7) Determine flexure strength, end diaphragm section. For noncompact sections with the beam compression flange laterally supported each 120 in., the moment strength is calculated using criteria in Chapter 2 and Equations 18 through 37. For this example, the flange local buckling is controlling,

$$\lambda_p < \lambda \le \lambda_r \tag{110}$$

and the acting moment at the end diaphram is

$$M_{ux_{ED}} = B_1 M_{nt} = 1.05\ (10{,}804.8)$$
$$= 11{,}345.04 \text{ kips-in.} \tag{111}$$

Using Equation 20, the moment strength is

$$M_n = M_p - (M_p - M_r)\left(\frac{\lambda - \lambda_p}{\lambda_r - \lambda_p}\right) \tag{112}$$

$$M_n = 38{,}088.72 - (38{,}088.72 - 13{,}404.0)$$
$$\times \left(\frac{12.0 - 10.8333}{24.0043 - 10.8333}\right)\left(\frac{1 ft}{12}\right) = 2{,}991.8\ kip\text{-}ft \tag{113}$$

$$M_n = 2{,}991.8 \text{ kip-ft} \tag{114}$$

$$\phi\alpha M_n = (0.9)\ (0.9)\ 2{,}991.8 = 2{,}423.4 \text{ kip-ft} \tag{115}$$

which is greater than M_{uxED} = 11,345.04 kip-in. Therefore, the section at the end diaphragm is acceptable for bending. Substituting

the values above into Equation 38 to determine if the end diaphragm section is acceptable for combining loads (axial and flexure),

$$0.503 + \frac{8}{9}\left(\frac{11{,}345.04}{29{,}080.8}\right) = 0.85 < 1.0 \tag{116}$$

Since this value is less than 1.0, the section at the end diaphragm is acceptable. At the midspan and end diaphragm locations, the chosen section is adequate for combined forces. The cross section consists of the following elements:

Upstream flange	12.0 by 0.5 in.
Downstream flange	12.0 by 0.5 in.
Skin plate	0.5 in.
Web	50.0 by 0.5 in.
Two longitudinal stiffeners	5.5 by 0.5 in.

End Diaphragm

For this example, the end diaphragm is designed using the critical load combination in panels 7 through 11. The end diaphragm is designed as a fixed plate (skin plate criteria) with the following dimensions (see Figure 174 for details):

$a = 48$ in.

$b1 = 29.5$ in.

$b2 = 20.5$ in.

$W_u = 2.787$ kips/ft^2 $= 0.0194$ ksi

$W = 1.935$ kips/ft^2 $= 0.0134$ ksi

$F_y = 36.0$ ksi

$F_r = 21$ ksi; load condition 2, category C

$\alpha = 0.9$

$\phi = 0.9$

a. *Required thickness based on yield limit state.* Equation 12 should be used to determine the end diaphragm thickness with $F = \alpha\phi F_y$, $W = W_u$, $\alpha = 0.9$, and $\phi = 0.9$:

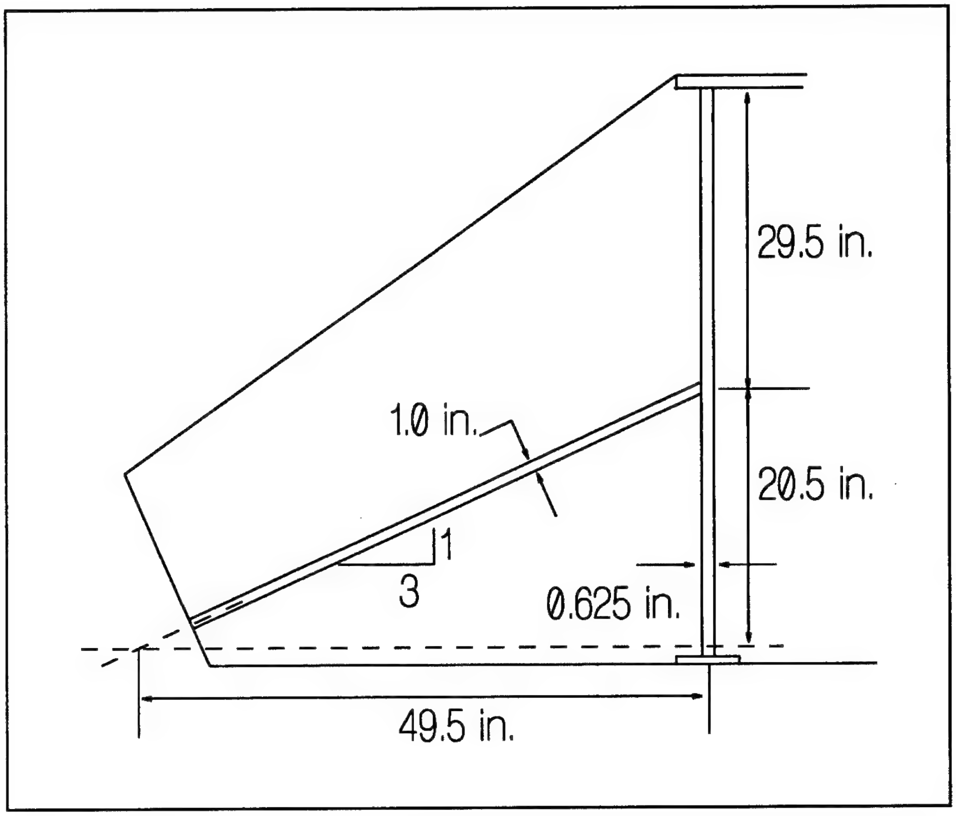


Figure 174. End diaphragm section

$$t_{\min} = \sqrt{\frac{0.9\ (0.0194)\ (29.5)^2}{29.16 \left[1 + 0.623 \left(\frac{29.5}{48}\right)^6\right]}} = 0.529 \text{ in.} \tag{117}$$

Use 0.625 in. Stress acting with $t = 0.625$ in.

$$\sigma = \frac{0.5\ W_u b^2}{\phi \alpha t^2 \left[1 + 0.623 \left(\frac{b}{a}\right)^6\right]} \tag{118}$$

$$\sigma = \frac{(0.5)\ (0.0194)\ 29.5^2}{(0.9)\ (0.9)\ (0.625)^2 \left[1 + 0.623 \left(\frac{29.5}{48}\right)^6\right]} = 25.8 \text{ ksi} \tag{119}$$

which is less than $F_y = 36.0$. Therefore, an end diaphragm plate thickness of 0.625 in. is acceptable for yield limit state.

b. Deflection check. Equation 11 should be used to calculate the deflection with $t = 0.625$ in. and $\delta_{all} = 0.4t$:

$$\delta = \frac{0.284\ (0.0134)\ (29.5)^4}{\left[1 + 1.056\left(\dfrac{29.5}{48}\right)^5\right](29{,}000)\ (0.0625)^3} = 0.0373 \text{ in.} \tag{120}$$

which is less than $\delta_{all} = 0.4t = 0.25$ in. Therefore, an end diaphragm plate thickness of 0.625 in. is acceptable for deflection criteria.

c. Minimum thickness required by fatigue. Equation 12 should be used to calculate the thickness required by fatigue with $F = F_r$, $W = W$ (AISC 1986):

$$t_{fat} = \sqrt{\frac{0.5\ (0.0134)\ (29.5)^2}{21\left[1 + 0.623\left(\dfrac{29.5}{48}\right)^6\right]}} = 0.511 \text{ in.} \tag{121}$$

The minimum thickness required by fatigue is 0.511 in.; use $t = 0.625$ in. (check with program to verify). Fatigue stress range using $t = 0.625$ is

$$\sigma = \frac{(0.5)\ (0.0134)\ 29.5^2}{(0.625)^2\left[1 + 0.623\left(\dfrac{29.5}{48}\right)^6\right]} = 14.46\ ksi \tag{122}$$

which is less than $F_r = 21.0$ ksi. Therefore, the end diaphragm plate thickness of 0.625 in. is acceptable for fatigue criteria. Since the end diaphragm with a thickness of 0.625 in. is acceptable for yield limit state, deflection, and fatigue, the end diaphragm with a thickness of 0.625 in. is acceptable.

Quoin Post

The quoin post will be designed using load combination 3 (Equation 8) with $H_t = 0.0$. For dimensions of the quoin post shown in Figure 175, the properties are as follow:

$A = 103.52$ in.^{2}

$C_x = 23.89$ in.

$C_y = 1.39$ in.

$I_x = 6{,}176.09$ in.^{4}

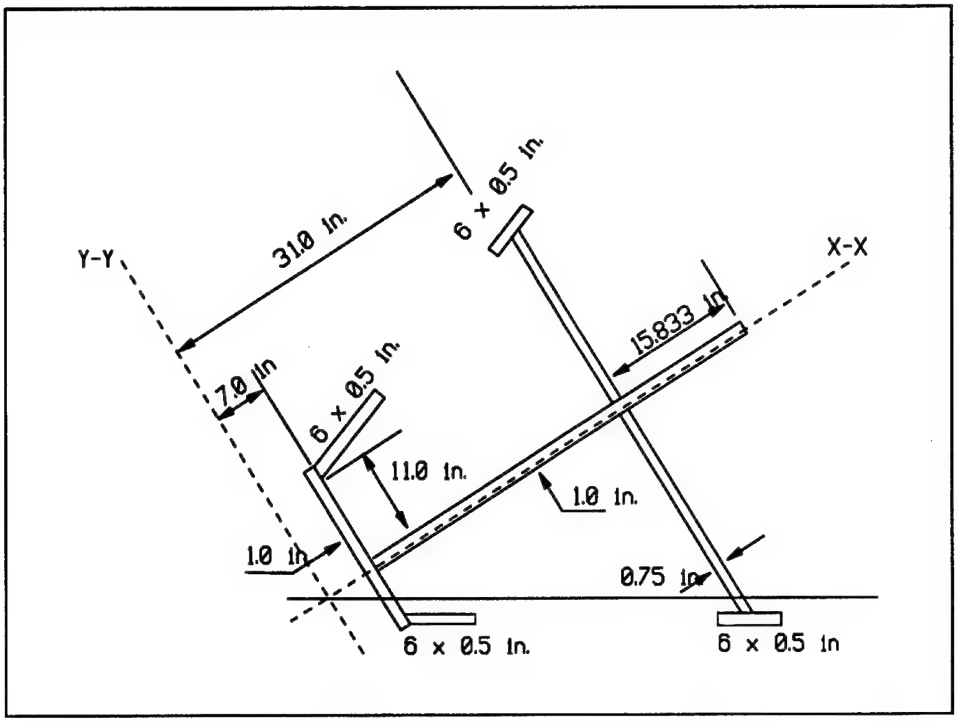


Figure 175. Quoin post section

$I_y = 14{,}691.10 \text{ in.}^4$

$X_{pin} = 27.27$ in.

$Y_{pin} = 6.71$ in.

$e_x = 3.38$ in.

$e_y = 5.32$ in.

$W_{gate} = 220.14$ kips

$C + M = 185.00$ kips

$P_u = 1.2\ W_{gate} + 1.6\ (C{+}M)$

$P_u = 560.17$ kips

$M_x = P_u(e_y) = 560.17(5.32) = 2{,}980.1$ kip-in.

$M_y = P_u(e_x) = 560.17(3.38) = 1{,}893.4$ kip-in.

The stresses acting in the quoin post should be determined in Points A through F, which are the most critical points (Figure 15), using the following equation:

$$\sigma = \frac{P}{\alpha\phi A} + \frac{M_x}{\alpha\Phi I_x}y + \frac{M_y}{\alpha\phi I_y}x \tag{123}$$

where

$x_a = -17.887$ in.

$y_a = 10.140$ in.

$x_b = -17.887$ in.

$y_b = -8.464$ in.

$x_c = 9.958$ in.

$y_c = 19.131$ in.

$x_d = 9.959$ in.

$y_d = -17.412$ in.

$x_e = -16.887$ in.

$y_e = -0.887$ in.

$x_f = -5.137$ in.

$y_f = -0.887$ in.

where the subscripts *a* through *f* correspond to the points in Figure 15. Substituting the values above in the stress equation, the stresses are:

$$\sigma_p = \frac{560.2}{(0.9)\ (0.85)\ 103.5} + \frac{2{,}980.1}{(0.9)\ (0.9)\ 6{,}176.09}(y_p) + \frac{1{,}893.4}{(0.9)\ (0.9)\ 14{,}691.1}(x_p) \tag{124}$$

$$\sigma_p = 7.05 + 0.596y_p + 0.159y_p \tag{125}$$

$\sigma_a = 10.23$ ksi

$\sigma_b = -0.88$ ksi

$\sigma_c = 20.04$ ksi

$\sigma_d = -1.78$ ksi

$\sigma_e = 3.80$ ksi

$\sigma_f = 5.68$ ksi

where all the stresses are less than $F_y = 36.0$ ksi. Therefore, the quoin post is acceptable.

Thrust Diaphragm

This example presents the design for the thrust diaphragm for panels 7 through 11 using the criteria in Chapter 2 (see Figure 176 for details).

a. *Axial load.* Determine the axial load using Equations 52, 53, and 54. A detailed explanation to determine the axial load acting in the thrust diaphragm is included in Chapter 2 (see Figure 14 for details).

$$W_U = 11.15 \text{ kips/ft}$$
$$L = 48.25 \text{ ft}$$
$$\theta = 18.43 \text{ deg} \tag{126}$$
$$V_a = W_u L \cos\theta = (11.15)(48.25)\cos(18.43) = 509.1 \text{ kips}$$

$$V = L \sin\theta = 15.26 \text{ ft}$$
$$H = L \cos\theta = 45.77 \text{ ft} \tag{127}$$

$$\sum M_{cp} = 0.0 \tag{128}$$

where M_{cp} = moment contact point.

$$V_a(H) - H_a(V) - \frac{W_u L^2}{2} = 0.0 \tag{129}$$

$$H_a = 678.8 \text{ kips} \tag{130}$$

$$R = V_a \sin(2\theta) + H_a \cos(2\theta) = 848.5 \text{ kips} \tag{131}$$

b. *Bending stress.* The bending stresses of the internal and external panels of the thrust diaphragm are calculated using the skin plate equations. The dimensions of the panel are as follows:

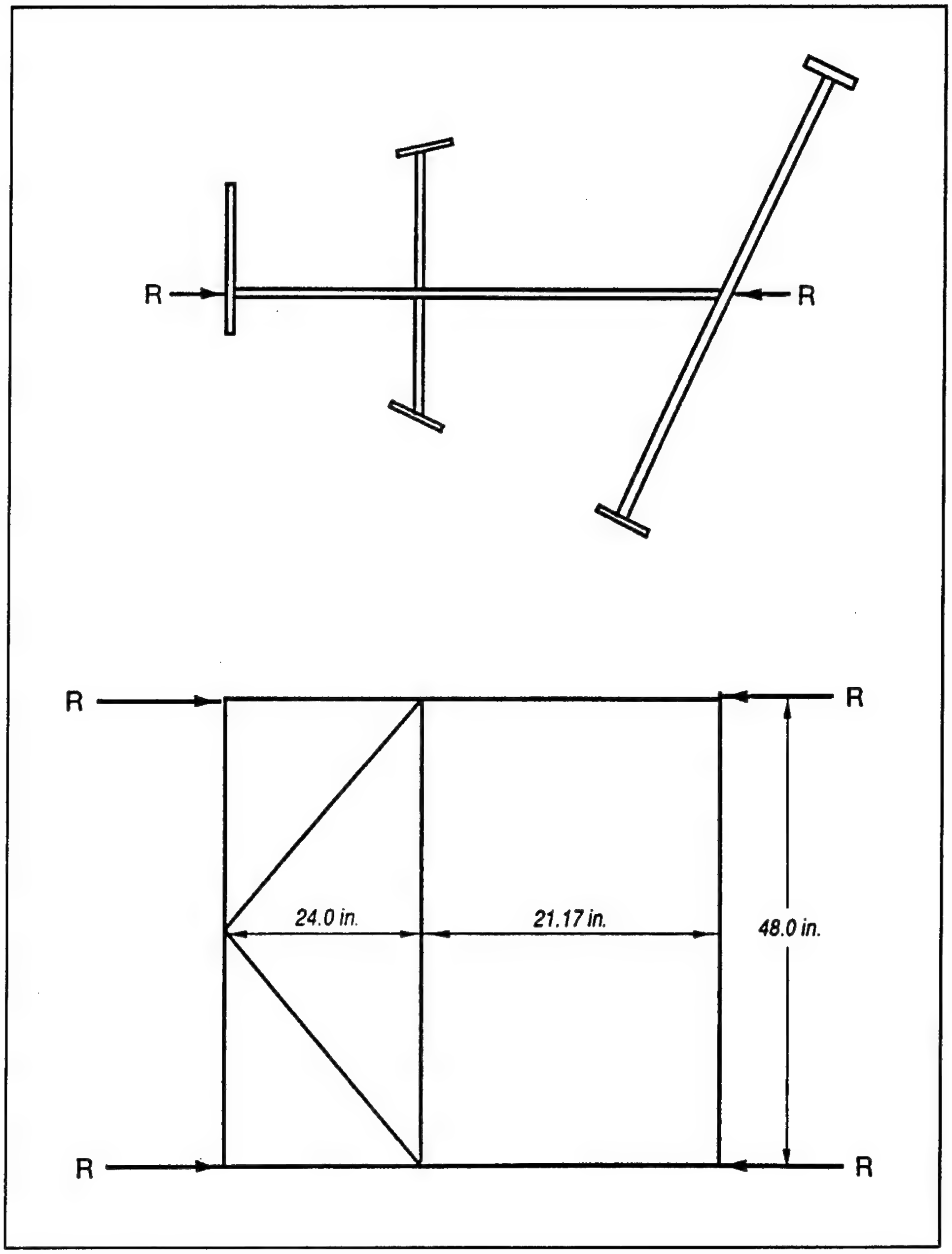


Figure 176. Thrust diaphragm section

$$a = 48 \text{ in.}$$

$$b_{int} = 21.17 \text{ in.}$$

$$b_{ext} = 24.00 \text{ in.}$$

$$q_{int} = 0.44$$

$$q_{ext} = 0.50$$

$t = 1.0$ in.

$Area = 1.0(48) = 48.0 \text{ in.}^2$

$\alpha = 0.9$

$\phi_a = 0.85$

$\phi_b = 0.9$

$W_u = 2.787 \text{ kips/ft}^2 = 0.01935$ ksi for load combination 2

$W = 1.935 \text{ kips/ft}^2 = 0.01344 \text{ kips/in.}^2$

c. *Yield limit state.*

$$\sigma = \frac{R}{\alpha \phi A} + \frac{0.5 W_u b^2}{\alpha \phi t^2 \left[1 + 0.623 \, (q^6)\right]} \tag{132}$$

$$\sigma = 29.9 \text{ ksi}$$

which is less than $F_n = F_y = 36.0$ ksi. Therefore, the thrust diaphragm section is acceptable for yield limit state.

d. *Deflection.*

$$\delta = \frac{0.0284 W b^2}{\left[1 + 1.056 \, (q^5)\right] E t^3} \tag{133}$$

$$\delta = \frac{0.0284 \; (0.01344) \; (24^2)}{\left[1 + 1.056 \; (0.5^5)\right] 29{,}000(1)^3} = 0.00422 \text{ in.} \tag{134}$$

which is less than $\delta_{all} = 0.4t = 0.4$ in. Therefore, the thrust diaphragm section for deflection criteria is acceptable.

e. *Fatigue.* With $F_r = 21.0$ ksi, load condition 2, category C,

$$\sigma_f = \frac{R}{A} + \frac{0.5 \; W b^2}{t^2 \left[1 + 0.623 \; (q^6)\right]} \tag{135}$$

$$\sigma_f = \frac{590.6}{48.0} + \frac{0.5 \; (0.0134) \; (24^2)}{(1.0^2) \left[1 + 0.623 \; (0.5^6)\right]} = 16.13 \text{ kips/in.}^2$$

which is less than $F_r = 21.0$ ksi. Therefore, the thrust diaphragm section is acceptable for fatigue criteria. Because the thrust diaphragm section is

acceptable for yield-limit state, deflection, and fatigue, it is totally acceptable.

Tapered End Section

The tapered end section is designed for girder 6, where the highest uniform load is located. The criteria to design this element are explained in Chapter 2 (Figure 11). See Figure 177 for geometric details.

For girder 6, the smaller span between adjacent girders is 5.0 ft, the thrust diaphragm thickness is 1.0 in., and critical section position Z′ is 22.0 in. (Figure 11).

The section properties at critical position are (see Figure 179):

$A = 42.59$ in.^{2} $\qquad$ $I_x = 3{,}048.90$ in.^{4}

$Y_{bot} = 12.81$ in. $\qquad$ $W_u = 11.37$ kips

$Y_{top} = 15.74$ in. $\qquad$ $R = 867.42$ kips

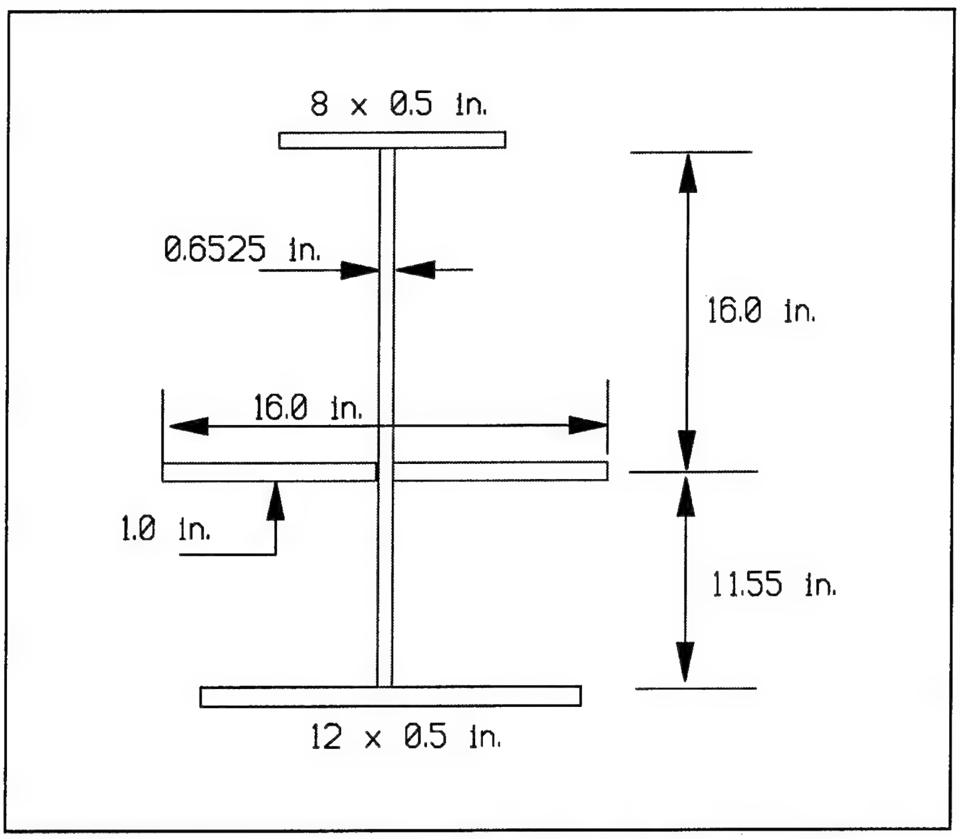


Figure 177. Tapered end section

Stresses acting in the tapered end section are as follows:

$$\sigma = \frac{P}{\alpha\phi A} + \frac{R\ (Y_{bot} - Y_{thrust})\ C}{\alpha\phi I_x} + \frac{W_u Z^2 C}{2\ \alpha\phi I_x} \tag{136}$$

$\sigma_{bot} = 31.09$ ksi

$\sigma_{top} = 20.76$ ksi

which are less than $F_y = 36.0$ ksi. Therefore, the tapered end section is acceptable.

Diagonals

This example pertains to design of the miter gate diagonal members utilizing ASTM A60 steel. Chapter 2 and AISC (1986) provide the general guidance for diagonal design. Diagonal design will be controlled by Equation 8 or 9. Equation 8 represents the case in which the gate is subjected to temporal hydraulic loading. Equation 9 represents the case in which a submerged obstruction constrains the gate leaf motion while the maximum operating force $Q1$ is applied. Plan and elevation views for the gate leaf are shown in Figure 178. The length of each diagonal is 723.7 in. The unfactored loads, the distance from the pintle to the applied loads z, the moment arm of the applied load with respect to the center of moments (located at the operating strut elevation), and corresponding load torque areas Tz for this case are shown in Table 7. For loads $Q1$, H_t, and H_d, a positive value of Tz indicates the case of gate opening and a negative value indicates the case of gate closing.

The factored loads for Equations 8 and 9 are as follows:

$Tz(D) = 1.2(-14{,}273.8) = -17{,}128.6$ kip-ft^2

$Tz(C+M) = 1.6(-14{,}383.1) = -23{,}012.9$ kip-ft^2

$Tz(Q) = 1.2(+279{,}352.0) = +335{,}222.4$ kip-ft^2

$Tz(H_t) = 1.0(+136{,}277.9) = +136{,}277.9$ kip-ft^2

The design strength for tension members is the lower of the following:

Case a. For yielding in the cross section, $\alpha = 0.9$, $\phi_t = 0.9$:

$P_n = F_y A_g$

$\alpha\phi_t F_y = 0.9\ (0.9)\ (60) = 48.6$ ksi

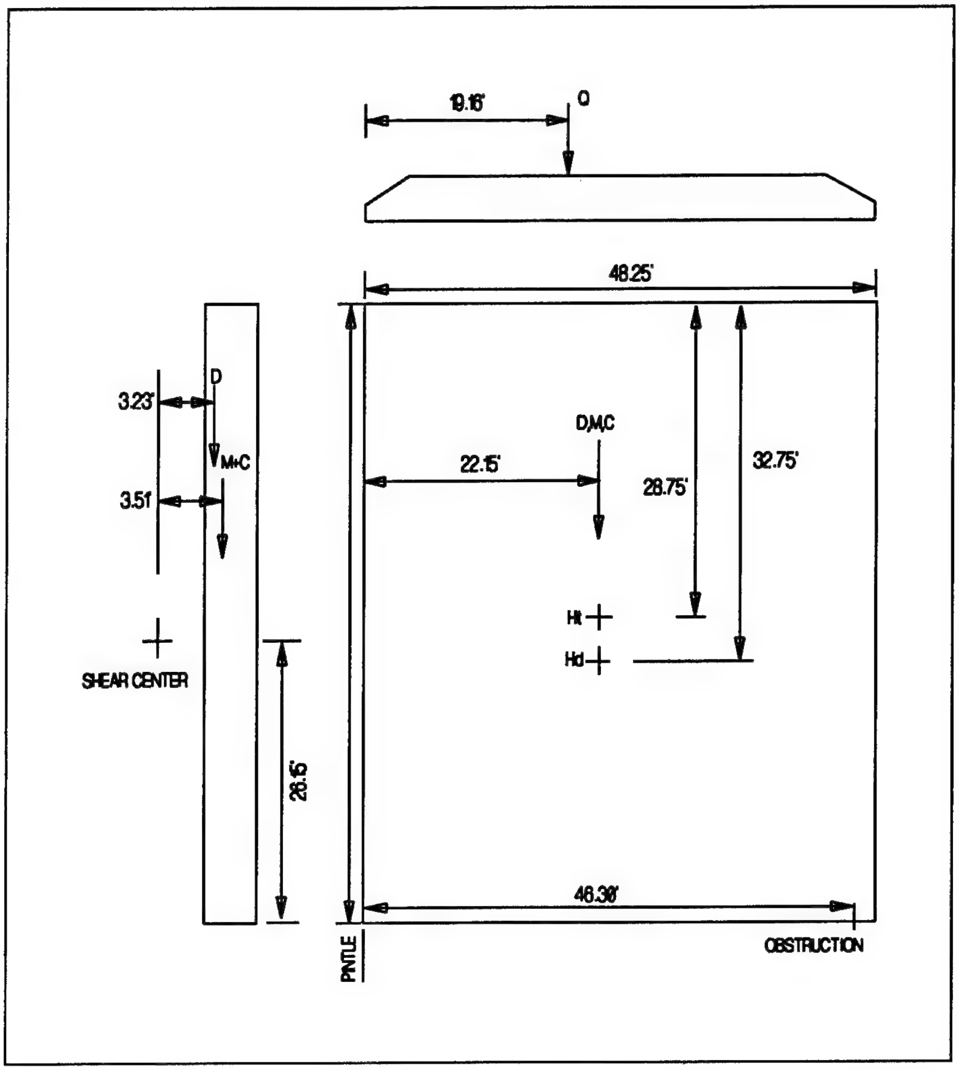


Figure 178. Plan and elevation views of the gate diagonals

Table 7
Gate Torsion Loads

Load	Force, kips	Moment Arm, ft	z, ft	Tz, kip-ft^2
D	199.51	3.23	22.15	-14,273.8
C + M	185.0	3.51	22.15	-14,383.1
Q1	106.0	56.92	46.30	±279,352
H_t	214.0	28.75	22.15	±136,278
H_d	70.93	32.75	22.15	±52,266.5

Case b. For fracture in the net section, $\alpha = 0.9$, $\phi_t = 0.75$:

$$P_n = F_u A_e = F_u (UA_g)$$

The end connections are welded to gusset plates with a total weld length greater than twice the bar width. Therefore, $U = 1.0$ and the effective area is the same as the gross area A_g (AISC 1986).

$$\alpha\phi_t F_u = 0.9(0.75)(75.0) = 50.63 \text{ ksi}$$

Case a controls and the limiting tensile stress is 48.6 ksi. Following the procedure in Chapter 2 used to obtain the diagonals' size, the following is obtained:

a. The stiffness of the leaf in deform the diagonal A' is the sum of the average cross-sectional areas of the two vertical and horizontal girders which bound the panels times 1/8.

$$A' = 19.06 \text{ in.}^2$$

b. The ratio of change in length R_o of diagonal to leaf deflection is calculated using Equation 61.

$$R_o = +0.123$$

c. The required size of the diagonals is calculated using Equation 62. Substituting values above into Equation 62:

$$A_p = \frac{\Sigma Tz}{sR_o hv} = -\frac{-375{,}363.9}{(48.6)\ (0.123)\ (55.0)\ (46.3)} \tag{137}$$

$$= 24.7 \text{ in.}^2$$

$$A_n = -\frac{\Sigma Tz}{sR_o hv} = -\frac{-335{,}224.4}{(48.6)\ (0.123)\ (55.0)\ (46.3)} \tag{138}$$

$$= 22.0 \text{ in.}^2$$

Use $A_p = 26.0$ in.^{2} and $A_n = 24.0$ in.^{2}.

d. The ratio R of the actual change in length of diagonals to deflection of the leaf is calculated using Equation 63 as follows:

$$R_p = \frac{A'}{A + A'} R_o = \left(\frac{19.06}{26.0 + 19.06}\right) (0.123) \tag{139}$$

$$= 0.0520$$

$$R_n = \frac{A'}{A + A'} R_o = \left(\frac{19.06}{24.0 + 19.06}\right) (0.123) \tag{140}$$

$$= 0.0544$$

e. Equation 64 is used to calculate the elasticity constant of a diagonal, which is:

$Q_p = 204{,}098.33$ kip-ft

$Q_n = 197{,}248.3$ kip-ft

f. The elasticity constant of the leaf without diagonals is calculated using Equation 58 as follows:

$$Q_o = 4E_s \sum\left(\frac{J}{H} + \frac{J}{v}\right) = \frac{4 \times 12{,}000}{12} \left(\frac{302.6}{660.0} + \frac{180.9}{555.6}\right) = 3{,}136.0 \text{ kip-ft} \tag{141}$$

g. For deflection of leaf, use Equation 65 to calculate the live-load gate-opening deflection (critical case is when $C + M = 0$),

$$\Delta_o = \frac{\Sigma\ Tz\ (Q)}{Q_o + \Sigma Q} = \frac{335{,}222.4}{404{,}022.6}\ 12.0 = 9.96 \text{ in.} \tag{142}$$

$$D^{+}_{\min} = 9.96 \text{ in.}$$

Use Equation 65 to calculate the live-load gate-closing deflection,

$$\Delta_o = \frac{\Sigma\ [Tz\ (C + M) - Tz\ (Q)]}{Q_o + \Sigma Q} = \frac{-358{,}235.3}{404{,}022.6}\ 12.0 = -10.64 \text{ in.} \tag{143}$$

$$D^{-}_{\min} = -10.64 \text{ in.}$$

h. Use Equation 66 to calculate the maximum numerical value of D,

$$D^{-}_{\max} = \frac{sL}{R_n E} + \Delta_n = \frac{48.6\ (723.7)}{-0.0545\ (29{,}000)} + 9.96 = -12.13 \text{ in.} \tag{144}$$

$$D^{+}_{max} = \frac{sL}{R_p E} + \Delta_p = \frac{48.6\ (723.7)}{0.052\ (29{,}000)} \tag{145}$$

$$-10.64 = 12.67 \text{ in.}$$

Use $D_p = 11.43$ in. and $D_n = -10.68$ in.

i. The stress in the diagonals must remain between the tension-limiting stress of 48.6 ksi and the minimum stress of 1.0 ksi (diagonals must always remain in tension). The maximum-tension stress will occur as follows:

For positive diagonals on gate closing (Equation 67),

$$s_p = \frac{R_p E}{L} (D_p - \Delta_c) = \frac{(0.0521)\ (29{,}000)}{723.7} \tag{146}$$

$$[11.43 - (-10.68)] = 46.16 \text{ ksi}$$

which is less than 48.5 ksi. Therefore, the positive diagonal is acceptable.

For the negative diagonal on gate opening,

$$s_n = \frac{R_n E}{L} (D_n - \Delta_o) = \frac{(0.0545)\ (29{,}000)}{723.7} \tag{147}$$

$$[-10.68 - (-9.99)] = 45.17 \text{ ksi}$$

which is less than 48.6 ksi. Therefore, the negative diagonal is acceptable.

References

American Institute of Steel Construction. (1986). *Load and resistance factor design manual of steel construction.* 1st ed., Chicago, IL.

_________. (1989). *Allowable stress design manual of steel construction.* 9th ed., Chicago, IL.

Elingwood, B. (1993). "Load and resistance factor design for steel miter gates," Instruction Report ITL-93-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Headquarters, Department of the Army. (1984). "Lock gates and operating equipment," Engineer Manual 1110-2-2703, Washington, DC.

_________. (1988). "User's guide for design and investigation of horizontally framed miter gates (CMITER)," Washington, DC.

_________. (1992). "Design of hydraulic steel structures," Engineer Manual 1110-2-2105, Washington, DC.

Timoshenko, S. P., and Woinowsky, S. (1959). *Theory of plates and shells.* 2nd ed., McGraw-Hill, New York.

Riveros, G. A. (1995). "User's guide: Computer program for the design and investigation of horizontally framed miter gates using the load and resistance factor design criteria (CMITER-LRFD)," Instruction Report ITL-95-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Appendix A CMITERW-LRFD Input Files Text Editor Format

The data file for CMITERW-LRFD is divided into four groups that will be explained in this appendix. The Group 1 data are always required, whereas Groups 2 and 3 data are for a detailed design or investigation. Group 4 data are used to change the default values. Each data line consists of a list name (three letters long) followed by the data items in the list. Data can be input in a free format. Values to be omitted must be input as a zero.

Group 1

Group 1 is required to run the RECDES, DES, and INV modules. Figure A1 and Table A1 show the data items of Group 1. As stated above, Group 1 is the only data group required to run the RECDES.

The following paragraphs explain each variable in Group 1. The x-coordinates are measured from the gate contact point toward the miter contact point in a direction parallel with the girder working line. The z-coordinates are measured upstream from the downstream edge of the girder web in a direction perpendicular to the work line.

JOB

Data list JOB (heading lines (at least one)). The maximum allowable number of heading (JOB) lines is five. If the title is more than one line, then all except the last line of the title must end with an asterisk. The JOB name should be used in each title line.

RGV

Data list RGV (required overall geometry, vertical). See Figure A1 for illustration. All values are in decimal feet.

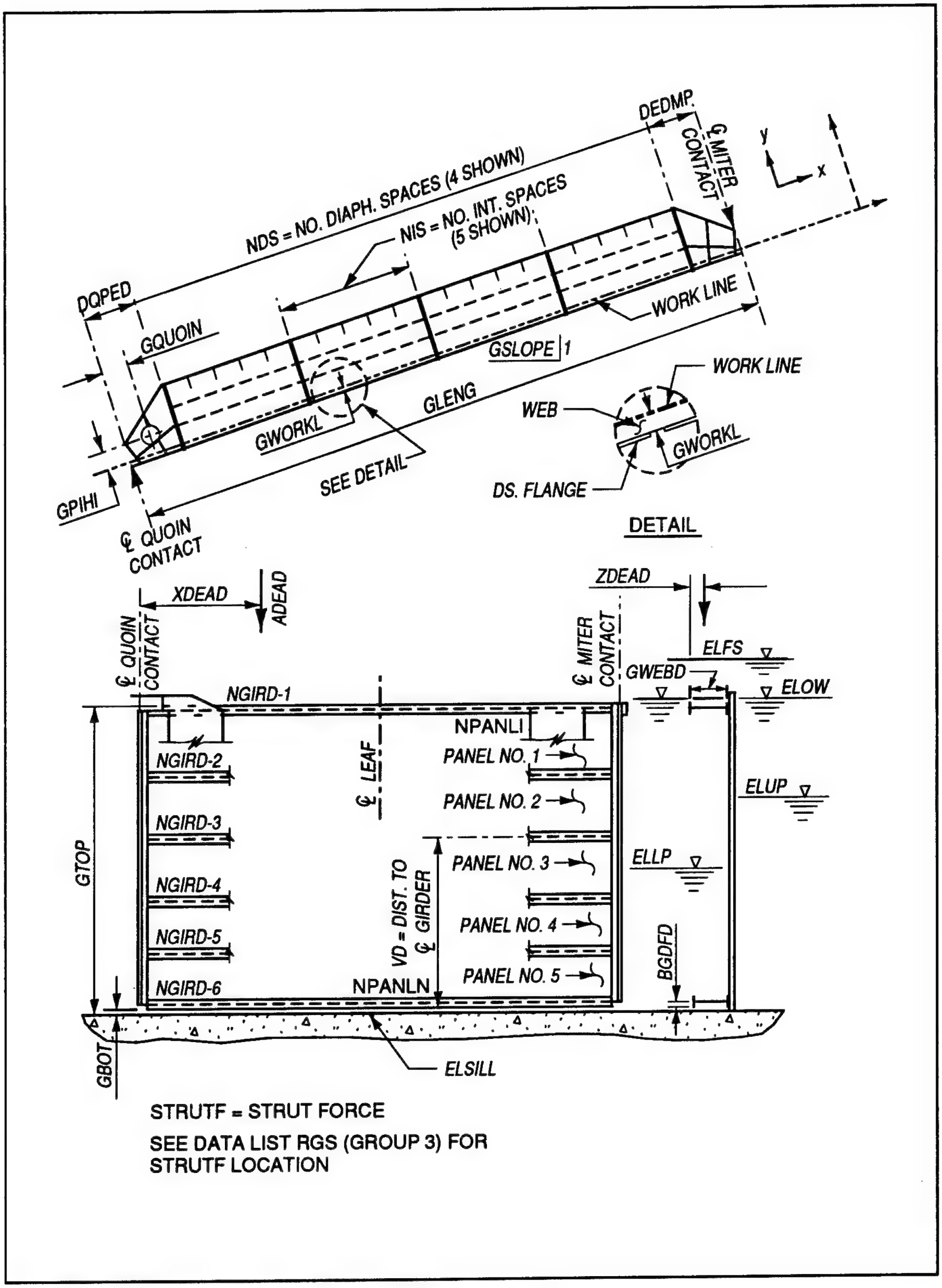


Figure A1. Group 1 data items

Table A1
Data File Group 1

List Name	Names of Data Items in the List					
JOB	Job Description Line					
RGV Figure A1	ELSILL	GBOT	GTOP			
RGL Figure A1	GLENG	GSLOPE	GWORKL	GQUOIN	GPIN1	
GCD Figure A1	GWEBD	DQPED	DEDMP	BGDFD		
GGC Figure A1	NGIRDS					
GWE Figure A1	NGIRD	VD				
GDS Figure A1	NPANLI	NPANLN	NDS	NIS		
RDL Figure A1	ADEAD	XDEAD	ZDEAD	ABUOY	XBUOY	ZBUOY
	ALIVE	STRUTF				
RWE Figure A1	ELUP	ELLP	ELFS	ELOW		
LCN	LC1	LC2	LC3	LC4	LC5	LC6
RSG Figure A1	FY	FYW	FYF	FYSK	FYS	FYI
	FYQ	FYD	FU			
FAT	LC	CATSK	CATI	CATG	CATEG	

RGV = name of data list.

ELSILL = elevation of sill above a given datum (must be positive).

GBOT = distance from sill to bottom of skin plate.

GTOP = distance from sill to overflow elevation at top of gate.

RGL

Data list RGL (required overall geometry, leaf). See Figure A1 for illustration. All values are in decimal feet.

RGL = name of data list.

GLENG = length of leaf between contact points.

GSLOPE = tangent of angle between the gate leaf and the lock center line when the gate is in the fully mitered position.

GWORKL = offset from gate leaf working line to downstream edge of girder web.

GQUOIN = distance along gate leaf working line from quoin contact point to gudgeon pin.

GPIN1 = offset from center of gudgeon pin to gate working line.

GCD

Data list GCD (girder geometry common dimensions). See Figure A1 for illustration. All values are in decimal inches. These dimensions are common to all girders.

GCD = name of data list.

GWEBD = girder web depth or the clear distance between girder flanges. Assume a value for the first trial $\left(\frac{L}{15} \leq d \leq \frac{L}{8}\right)$ where L is the girder length.

DQPED = distance from quoin contact point to center of nearest end diaphragm, measured along the gate working line.

DEDMP = distance from center of end diaphragm at miter end of gate to miter contact point, measured along gate working line.

BGDFD = bottom girder downstream flange downward extension below the center line (usual value is 3 in.).

GGC

Data list GGC (girder geometry control). See Figure A1 for illustration.

GGC = name of data list.

NGIRDS = number of girders in leaf.

GWE

Data list GWE (girder web elevations). See Figure A1 for illustration. All values are in feet. Repeat the list for each girder.

GWE = name of data list.

NGIRD = girder number (one at top and NGIRDS at bottom of gate).

VD = vertical distance between the sill and the girder web center line.

GDS

Data list GDS (girder diaphragm spacing). Repeat the list for each group of skin plate panels. See Figure A1 for illustration.

GDS = name of data list.

NPANLI = girder number at top of panel group.

NPANLN = girder number at bottom of panel group.

NDS = number of diaphragm spaces between end diaphragms, along the gate leaf.

NIS = number of intercostal spaces between adjacent diaphragms.

Note: A panel group refers to panels that have the same number of intercostals and the same skin plate thickness.

RDL

Data list RDL (required dead loads). Respective units are shown with each item. Coordinates are as described for data list GCD. See Figure A1 for illustration.

RDL = name of data group.

ADEAD = concentrated additional dead load, including mud and ice, bridgeway or walkway, intermediate diaphragm stiffeners, gusset plates, etc., pounds total force. (Gate weight should not be included here.)

XDEAD = distance along gate working line from quoin contact point (x-coordinate) to centroid of ADEAD, feet (a value of zero will set it at the middle of GLENG).

ZDEAD = offset from downstream edge of girder web to centroid (z-coordinate) of ADEAD, inches.

ABUOY = buoyancy force acting on dry weight of gate, pounds (INV module only).

XBUOY = distance along gate working line from quoin contact point (x-coordinate) to centroid of ABUOY, feet (a value of zero will set it at the middle of GLENG) (INV module only).

ZBUOY = offset from downstream edge of girder web to centroid (Z-coordinate) of ABUOY, inches (INV module only).

ALIVE = uniformly applied live load, including walkway and bridgeway, total pounds (INV module only).

STRUTF = strut capacity force, pounds, applied by strut arm in Load Case 5 (obstruction).

RWE

Data list RWE (required water elevations). Elevations are in feet above the same datum as ELSILL. See Figure A1 for illustration.

RWE = name of data list.

ELUP = elevation of upper pool.

ELLP = elevation of lower pool.

ELFS = temporal head elevation.

ELOW = operating water elevation.

LCN

Data list LCN (load combination numbers). Values are one or zero. Use one to activate the load combination and zero to deactivate the load combination. (See page 11, main text, for details.)

LCN = name of data list.

LC1, LC2, . . . , LC6 = load combination numbers.

LC3 = Equation 6 with I = 0.0 and ELLP = 0.

RSG

Data list RSG (required steel grades). Values of yield stress should be in kips per square inch.

RSG = name of data list.

FY = yield strength of all steel not specifically listed for one of the other items in the list.

FYW = yield strength of the steel in girder webs.

FYF = yield strength of the steel in the girder flanges.

FYSK = yield strength of the steel in the skin plate.

FYS = yield strength of the steel in the girder stiffeners.

FYI = yield strength of the steel in the intercostals.

FYQ = yield strength of the steel in the quoin post.

FYD = yield strength of the steel in the diagonals.

FU = maximum diagonal tensile strength.

FAT

Data list FAT (fatigue load condition and fatigue categories). Fatigue values included in CMITER-LRFD for load condition and fatigue categories are those specified in AISC (1986).

FAT = name of data list.

LC = load condition of the gate.

CATSK = fatigue category of the skin plate.

CATI = fatigue category of the intercostal.

CATG = fatigue category of the girders.

CATGE = fatigue category of the girders at end diaphragm.

Group 2

The data in Group 2 (Table A2) are required to run the INV module. The DES module must be run if the user wants to set the dimensions of the horizontal girders and intercostals. When designed, the data in Group 2 can be omitted and the program will then calculate these values (Figure A2).

Table A2
Data File Group 2

List Name	Names of Data Items in the List					
GWT Figure A2	NGIRDI	NGIRDN	GWET	GWCT		
GFU Figure A2	NGIRDI	NGIRDN	GUFEW	GUFET	GUF34W	GUF4CW
	GUFCT	GUCPX	GUCPW	GUCPT		
GFD Figure A2	NGIRDI	NGIRDN	GDFEW	GDFET	GDFCW	GDFCT
	GDCPX	GDCPW	GDCPT			
GFC Figure A2	NGIRDI	NGIRDN	GUFX4	GDFX5		
GWS Figure A2	NGIRDI	NGIRDN	NGWTS	NGLS	GLS1D	GLS1W
	GLS1T	GLS2D	GLS2W	GLS2T	GLS3D	GLS3W
	GLS3T					
ISG Figure A2	NGIRDI	NGIRDN	SPT	ODI	STEMT	FWI
	FTI					

GWT

Data list GWT (girder web thicknesses). The minimum thickness for design is established by TMGW in data list DMT (Group 4). Values are in inches. Use once for each group of adjacent girders with the same web thicknesses (see Figure A2 for illustration). Data list DMT in Group 4 shows default minimum values and how to change them.

GWT = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

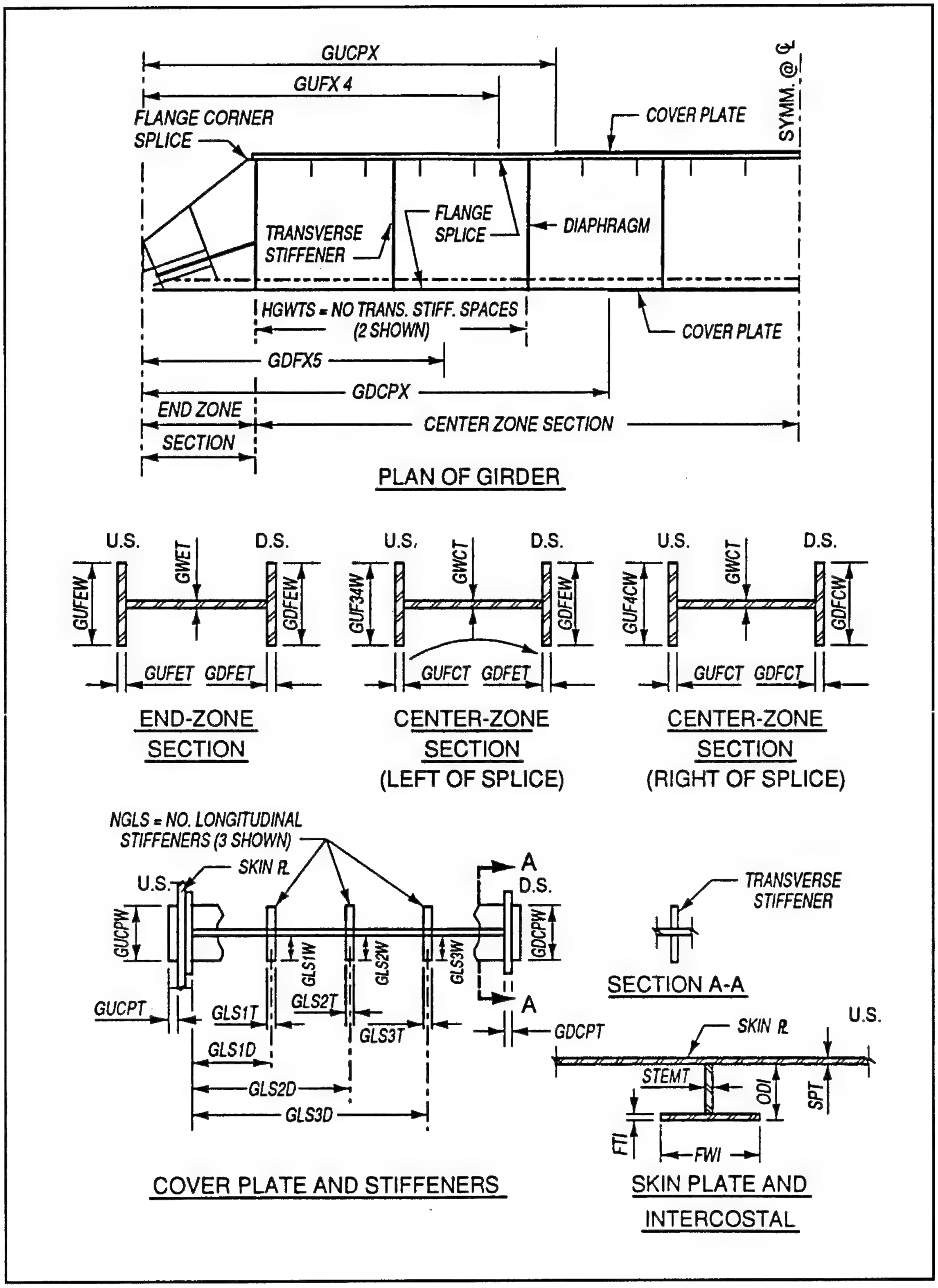


Figure A2. Group 2 data items

GWET = girder web end zone thickness in quoin post area.

GWCT = girder web center zone thickness between end diaphragms.

GFU

Data list GFU (girder flange, upstream). The minimum thicknesses for design are established by TMGW in data list DMT (Group 4). Values are in inches. Use once for each group of adjacent girders with the same flange description (see Figure A2 for illustration).

GFU = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

GUFEW = girder upstream flange end zone width from girder end to corner splice.

GUFET = girder upstream flange end zone thickness from girder end to corner splice.

GUF34W = girder upstream flange width from corner splice point to flange splice point.

GUF4CW = girder upstream flange width from flange splice point to girder center line.

GUFCT = girder upstream flange thickness from corner splice point, through flange splice point, to girder center line, and thickness of intermediate diaphragm upstream flange.

GUCPX = girder upstream cover plate end x-coordinate.

GUCPW = girder upstream cover plate width.

GUCPT = girder upstream cover plate thickness.

GFD

Data list GFD (girder flange, downstream). The minimum thicknesses for design are established by TMGW in data list DMT (Group 4). Values are in inches. Use once for each group of adjacent girders with the same flange description (see Figure A2 for illustration).

GFD = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

GDFEW = girder downstream flange end zone width from girder end to splice point.

GDFET = girder downstream flange end zone thickness from girder end to splice point.

GDFCW = girder downstream flange center zone width from splice point to girder center line.

GDFCT = girder downstream flange center zone thickness from splice point to girder center line.

GDCPX = girder downstream flange cover plate end x-coordinate.

GDCPW = girder downstream cover plate width.

GDCPT = girder downstream cover plate thickness.

GFC

Data list GFC (girder flange, x-coordinates). Use once for each group of adjacent girders with the same flange description. Dimensions are in inches (see Figure A2 for illustration).

GFC = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

GUFX4 = girder upstream flange x-coordinate of flange splice point.

GDFX5 = girder downstream flange x-coordinate of flange splice point.

GWS

Data list GWS (girder web stiffeners). Use once for each group of adjacent girders with the same stiffener description. Dimensions are in inches (see Figure A2 for illustration).

GWS = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

NGWTS = number of girder web transverse stiffener spaces between adjacent intermediate diaphragms. Use zero if there are no stiffeners.

NGLS = number of girder longitudinal stiffener pairs to be used. If more than one pair is used, Pair 1 will be upstream of Pair 2, and Pair 2 will be upstream of Pair 3.

GLS1D = girder longitudinal Stiffener 1, distance from upstream edge of web to center of stiffener plate.

GLS1W = girder longitudinal Stiffener 1, width of each plate in the pair. Use negative value if stiffeners are only on one side of web.

GLS1T = girder longitudinal Stiffener 1, thickness of each plate.

GLS2D = girder longitudinal Stiffener 2, distance from upstream edge of web to center of stiffener plate in Pair 2. Must be less than GLS1D. Use zero if NGLS is less than two.

GLS2W = girder longitudinal Stiffener 2, width of each plate in the pair. Use negative value if stiffeners are only on one side of web. Use zero if NGLS is less than two.

GLS2T = girder longitudinal Stiffener 2, thickness of each plate. Use zero if NGLS is less than two.

GLS3D = girder longitudinal Stiffener 3, distance from upstream edge of web to center of stiffener plate in Pair 2. Must be less than GLS2D. Use zero if NGLS is less than three.

GLS3W = girder longitudinal Stiffener 3, width of each plate in the pair. Use negative value if stiffeners are only on one side of web. Use zero if NGLS is less than three.

GLS3T = girder longitudinal Stiffener 3, thickness of each plate. Use zero if NGLS is less than three.

ISG

Data list ISG (intercostal and skin plate geometry). ISG defines the intercostal size and spacing and skin plate thickness for both investigation and design. Repeat the list for each group of skin plate panels (see Figure A2 for illustration).

ISG = name of data list.

NGIRDI = girder number at top of group of girders.

NGIRDN = girder number at bottom of group of girders.

SPT = skin plate thickness. The minimum thickness for design is established by TMSP in data list DMT (Group 4). All values are in inches.

ODI = overall depth of intercostal stem, including FTI, perpendicular to skin plate.

STEMT = thickness of intercostal stem.

FWI = flange width of intercostal (T-section).

FTI = flange thickness of intercostal (T-section).

Group 3

The data in Group 3 (Table A3) are required to run the DES module if the design of the following detailed elements is desired: end diaphragms, quoin post, thrust diaphragm, tapered end section, and diagonals (Figures A3 and A4). The items marked with an asterisk may be entered as zero and the program will calculate them.

RGS

Data list RGS (required geometry for struts). All values are in decimal feet (See Figure A4 for illustration).

RGS = name of data list.

GSTRT1 = distance along gate working line from gudgeon pin to strut pin, at top girder.

GSTRT3 = vertical distance from center line of top girder up to strut connection point.

RED

Data list RED (required end diaphragm description). All values are in inches (Figure A3).

RED = name of data list.

EDT = end diaphragm web thickness. For design purposes use a value of zero.

Table A3 Data File Group 3						
List Name	**Names of Data Items in the List**					
RGS Figure A4	GSTRT1	GSTRT3				
RED Figure A3	EDT*	EDUFW	EDDFW	EDDFT		
RID Figure A3	DUFW	DDFW	DDFT	DWT		
RQP Figure A3	GUFX3	TDSLOC	CPLOC	CPUW	QCPT	QCPSW
	QCPST	QTDT*	QDST	QDSUFW	QDSDFW	QDSFT
	TDHSA					
RDH Figure A4	NDPH	DX1Q	DX1M	DX2Q	DX2M	DX3Q
	DX3M					
RDV Figure A4	NDPV	DTD	DBU	NDG1	DG1U	DG1D
	NDG2	NG2U	DG2D			
RDW	DDSN	DDSP				
* Enter as zero. Program will calculate.						

EDUFW = end diaphragm upstream flange width.

EDDFW = end diaphragm downstream flange width.

EDDFT = end diaphragm downstream flange thickness. (Upstream flange thickness is GUFCT in data list GFU (Group 2).)

RID

Data list RID (required intermediate diaphragm description). All values are in inches (Figure A3).

RID = name of data list.

DUFW = diaphragm upstream flange width.

DDFW = diaphragm downstream flange width.

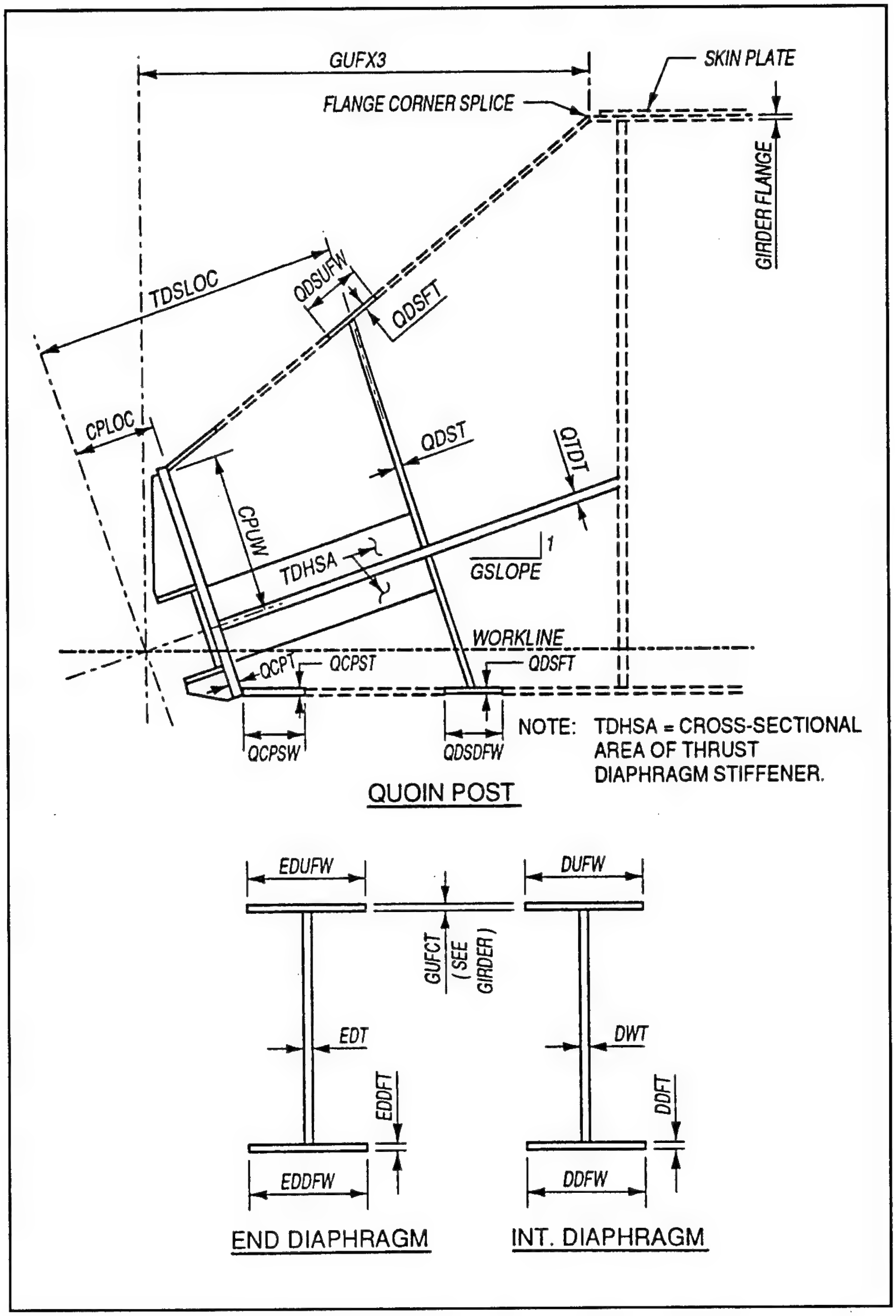


Figure A3. Group 3, quoin, tapered end, and end diaphragm data

DDFT = diaphragm downstream flange thickness. (The upstream flange thickness is set by GUFCT in data list GFU (Group 2).)

DWT = diaphragm web thickness.

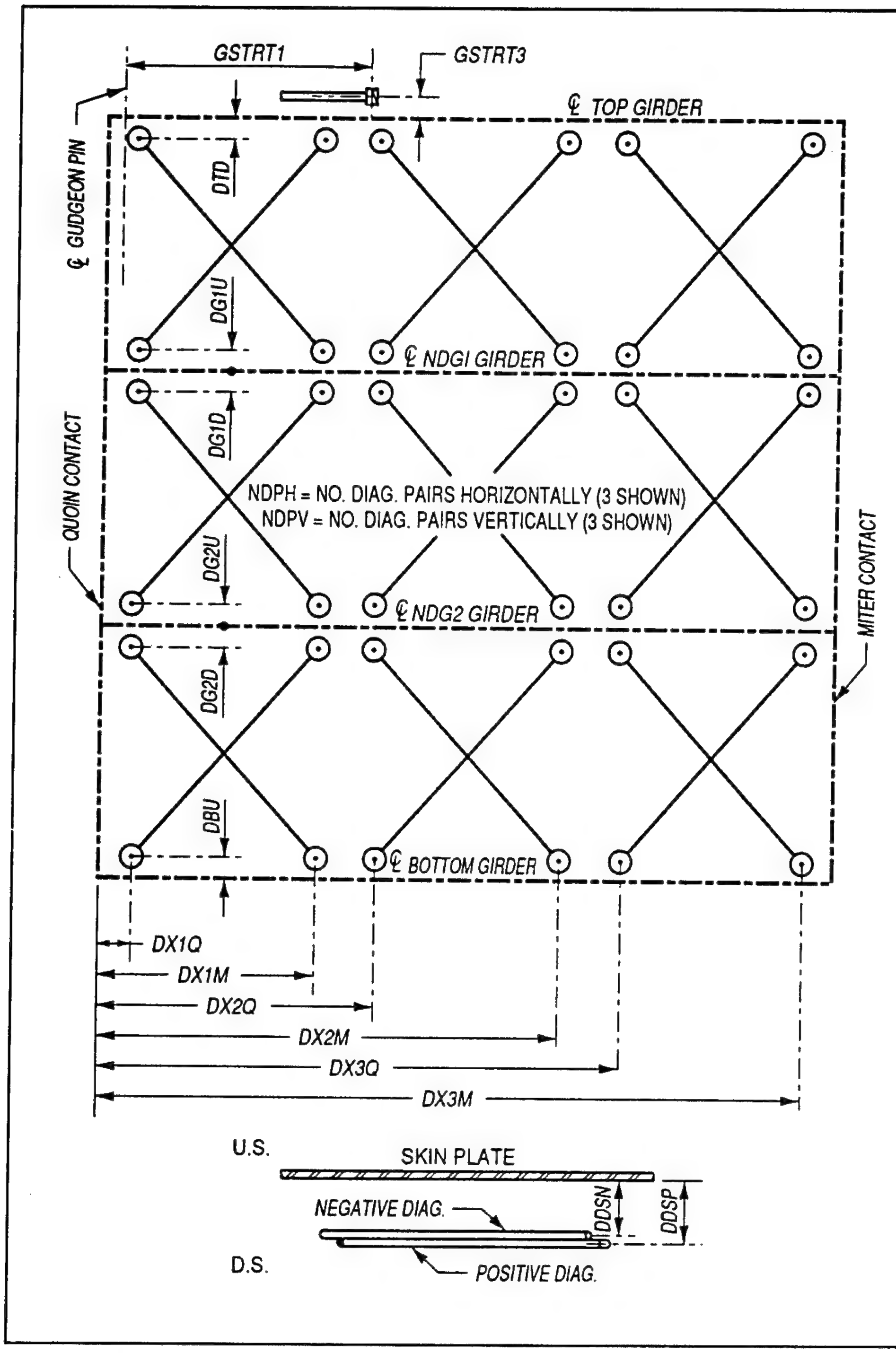


Figure A4. Group 3, diagonals

RQP

Data list RQP (required data for quoin post). All values are in inches except TDHSA, which is in square inches (Figure A3).

RQP = name of data list.

GUFX3 = girder upstream flange x-coordinate of corner splice point.

TDSLOC = thrust diaphragm stiffener plate location, distance along thrust diaphragm from quoin contact point to center of thrust diaphragm stiffener plate.

CPLOC = distance along line of thrust diaphragm from quoin contact point to the inside edge of the end plate.

CPUW = quoin post contact plate width from center line of the thrust diaphragm to upstream corner of the end plate. The downstream partial width is calculated by the program.

QCPT = quoin post contact plate thickness.

QCPSW = quoin post contact plate stiffener width.

QCPST = quoin post contact plate stiffener thickness.

QTDT = quoin post thrust diaphragm thickness. A value of zero will cause the QTDT to be selected by the program.

QDST = quoin post thrust diaphragm stiffener plate thickness.

QDSUFW = quoin post thrust diaphragm stiffener plate upstream flange width. Use a value of zero to omit the upstream half of the stiffener plate and its flange.

QDSDFW = quoin post thrust diaphragm stiffener plate downstream flange width. Use a value of zero to omit the downstream half of the stiffener plate and its flange.

QDSFT = quoin post thrust diaphragm stiffener plate flange thickness.

TDHSA = thrust diaphragm horizontal stiffener cross-section area, square inches. This stiffener is horizontal, extending from the contact plate to the end diaphragm, located halfway up in the space between girder webs. Use a value of zero to omit this plate.

RDH

Data list RDH (required diagonal geometry, horizontal). This data list describes the x-coordinates along the gate working line from the quoin contact point to the ends of diagonals and the eccentricities normal to the skin plate. The x-coordinate values in this group are in pairs, one pair of coordinate values for each pair of diagonals horizontally (Figure A4). All x-coordinates are in inches.

RDH = name of data list.

NDPH = number of diagonal pairs, horizontally (three maximum).

DX1Q = x-coordinate of diagonal pair end toward the quoin, first pair.

DX1M = x-coordinate of diagonal pair end toward the miter end, first pair.

DX2Q = x-coordinate of diagonal pair end toward the quoin, second pair.

DX2M = x-coordinate of diagonal pair end toward the miter end, second pair.

DX3Q = x-coordinate of diagonal pair end toward the quoin, third pair.

DX3M = x-coordinate of diagonal pair end toward the miter end, third pair.

RDV

Data list RDV (required diagonal geometry, vertical). This data list describes the vertical relationship between the diagonal ends and the gate vertical geometry (Figure A4). Values are in inches.

RDV = name of data list.

NDPV = number of diagonal pairs vertically.

DTD = distance from topmost girder web down to highest diagonal end.

DBU = distance from bottom girder web up to lowest diagonal end.

NDG1 = girder number at the bottom of the topmost diagonal pair panel (use if NDPV is two or three).

DG1U = distance from the web of the girder NDG1 up to lower end of diagonal pair in the topmost diagonal panel (use if NDPV is two or three).

DG1D = distance from the web of the girder NDG1 down to the upper end of diagonal pair in the diagonal panel inmediately below the girder (use if NDPV is two or three).

NDG2 = girder number at the top of the bottom diagonal panel, the third diagonal panel (use if NDPV is three).

DG2U = distance from the web of the girder NDG2 up to lower end of diagonal pair in the middle diagonal panel.

DG2D = distance from the web of the girder NDG2 down to the upper end of diagonal pair in the bottom diagonal panel.

RDW

Data list RDW (required diagonal geometry). This data list defines the horizontal offset from the skin plate to the diagonals. Values are in inches (Figure A4).

RDW = name of data list.

DDSN = distance from downstream face of skin plate to center line of negative diagonals.

DDSP = distance from downstream face of skin plate to center line of positive diagonals.

Group 4

Group 4 (Table A4) is required only if the user wants to change the default values used for certain items and when the load combination 6 is active.

Table A4
Data File Group 4

List Name	Names of Data Items in the List					
DMT	TMSP	TMED	TMI	TMGW	TMGF	
DEF	HEAD1	HEAD2	OBSLOC	THEAD	OWP	UWW
	EQAF	USYM	SYM			

DMT

Data list DMT (design minimum thickness). Each item in this list includes the default value that is specified if the list is not entered. Values are in inches.

DMT = name of the data group.

TMSP = minimum thickness of skin plate (SPT in data list ISG (Group 2)). Default value = 0.375 in.

TMED = minimum thickness of end diaphragms (EDT in data list RED (Group 3)). Default value = 0.5 in.

TMI = minimum thickness of intercostal (data list ISG (Group 2)). Default value = 0.375 in.

TMGW = minimum thickness of girder webs (GWET and GWCT in data list GWT (Group 2)). Default value = 0.375 in.

TMGF = minimum thickness of girder flanges (data groups GFU and GFD (Group 2)). Default value = 0.5 in.

DEF

Data list DEF (default values for load data). This data list allows changing the default values for hydraulic and impact load data.

DEF = name of the data group.

HEAD1 = feet of water to be used as a minimum head for analysis of skin plate. Default value = 6.0 ft.

HEAD2 = feet of water to be used as a minimum head for impact analysis of girders in ASD criteria. A value of zero is used in LRFD criteria.

OBSLOC = obstruction location radius from pintle, feet. If not changed by data group DEF, the default value will be placed at the miter point. Use any number if STRUTF = 0.

THEAD = temporal head, feet of water, applied from the full submergence elevation ELFS down to the gate bottom. Default value = 1.25 ft.

OWP = operating water pressure, pounds per square inch, applied from the operating water elevation ELOW to the gate bottom. Default value = 30.0 psf.

UWW = unit weight of water, pounds per cubic foot. Default value = 62.5 pcf.

EQAF = earthquake acceleration factor to be used in Westergaard's equation to determine dynamic water pressures. Default value = 0.05.

USYM = unsymmetric impact load, kips. Default value = 250.0 kips.

SYM = symmetric impact load, kips. Default value = 400.0 kips.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY *(Leave blank)*	2.REPORT DATE	3.REPORT TYPE AND DATES COVERED
	September 1996	Final report

4.TITLE AND SUBTITLE
User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Criteria (CMITERW-LRFD) Windows Version

5.FUNDING NUMBERS

6.AUTHOR(S)
Guillermo A. Riveros

7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Instruction Report
ITL-96-3

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
Available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT ***(Maximum 200 words)***

This report is the user's manual for the CMITERW-LRFD computer program, which is used to design and investigate horizontally framed miter gates with the skin plate in the upstream flange, using the load and resistance factor design criteria (LRFD). LRFD criteria offer more uniform reliability and a possibility of economy that is achieved in the design process.

CMITERW-LRFD is organized into three distinct functions: the Recommended Design Module (RECDES), which performs calculations that will help to establish meaningful values required to start the design; the Design Module (DES), which performs calculations to design a gate leaf; and the Investigation Module (INV), which can be used to investigate an existing gate leaf or to verify a design.

The CMITERW-LRFD runs under Windows environment and includes a graphic interface that allows the user to generate the input files required to run each module by the presence of graphics and sketches. The interface also provides the ability to edit an existing input file. The program also includes a graphic postprocessor that allows the user to see the program results graphically.

This report presents results of RECDES, DES, and INV modules for an example of a structure originally designed using allowable stress design criteria.

14.SUBJECT TERMS

Computer program	Hydraulic steel structures
Horizontally framed miter gates	Load and resistance factor design

15.NUMBER OF PAGES
194

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982
Instruction Report K-83-1	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide: A Three-Dimensional Stability Analysis/Design Program (3DSAD) Module	Jun 1987
	Report 1: Revision 1: General Geometry	Jun 1987
	Report 2: General Loads Module	Sep 1989
	Report 6: Free-Body Module	Sep 1989

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Instruction Report ITL-87-4	User's Guide: 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies–Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies–Closed Sections Report 5: Alternate Configuration Miter Gate Finite Element Studies–Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume I, User's Manual	Aug 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987
Instruction Report ITL-87-6	Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	Dec 1987
Technical Report ITL-87-8	Procedure for Static Analysis of Gravity Dams Using the Finite Element Method – Phase 1a	Jan 1988
Instruction Report ITL-88-1	User's Guide: Computer Program for Analysis of Planar Grid Structures (CGRID)	Feb 1988
Technical Report ITL-88-1	Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils	Apr 1988
Technical Report ITL-88-2	User's Guide: Pile Group Graphics Display (CPGG) Post-processor to CPGA Program	Apr 1988
Instruction Report ITL-88-2	User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER)	Jun 1988
Instruction Report ITL-88-4	User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT)	Sep 1988
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume II, Theory	Feb 1989
Technical Report ITL-89-3	User's Guide: Pile Group Analysis (CPGA) Computer Group	Jul 1989
Technical Report ITL-89-4	CBASIN–Structural Design of Saint Anthony Falls Stilling Basins According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0098	Aug 1989

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Technical Report ITL-89-5	CCHAN–Structural Design of Rectangular Channels According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0097	Aug 1989
Technical Report ITL-89-6	The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II	Aug 1989
Contract Report ITL-89-1	State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures	Sep 1989
Instruction Report ITL-90-1	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)	Feb 1990
Technical Report ITL-90-3	Investigation and Design of U-Frame Structures Using Program CUFRBC Volume A: Program Criteria and Documentation Volume B: User's Guide for Basins Volume C: User's Guide for Channels	May 1990
Instruction Report ITL-90-6	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame or W-Frame Structures (CWFRAM)	Sep 1990
Instruction Report ITL-90-2	User's Guide: Pile Group–Concrete Pile Analysis Program (CPGC) Preprocessor to CPGA Program	Jun 1990
Technical Report ITL-91-3	Application of Finite Element, Grid Generation, and Scientific Visualization Techniques to 2-D and 3-D Seepage and Groundwater Modeling	Sep 1990
Instruction Report ITL-91-1	User's Guide: Computer Program for Design and Analysis of Sheet-Pile Walls by Classical Methods (CWALSHT) Including Rowe's Moment Reduction	Oct 1991
Instruction Report ITL-87-2 (Revised)	User's Guide for Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-89	Mar 1992
Technical Report ITL-92-2	Finite Element Modeling of Welded Thick Plates for Bonneville Navigation Lock	May 1992
Technical Report ITL-92-4	Introduction to the Computation of Response Spectrum for Earthquake Loading	Jun 1992
Instruction Report ITL-92-3	Concept Design Example, Computer-Aided Structural Modeling (CASM) Report 1: Scheme A Report 2: Scheme B Report 3: Scheme C	 Jun 1992 Jun 1992 Jun 1992
Instruction Report ITL-92-4	User's Guide: Computer-Aided Structural Modeling (CASM) -Version 3.00	Apr 1992
Instruction Report ITL-92-5	Tutorial Guide: Computer-Aided Structural Modeling (CASM) -Version 3.00	Apr 1992

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Contract Report ITL-92-1	Optimization of Steel Pile Foundations Using Optimality Criteria	Jun 1992
Technical Report ITL-92-7	Refined Stress Analysis of Melvin Price Locks and Dam	Sep 1992
Contract Report ITL-92-2	Knowledge-Based Expert System for Selection and Design of Retaining Structures	Sep 1992
Contract Report ITL-92-3	Evaluation of Thermal and Incremental Construction Effects for Monoliths AL-3 and AL-5 of the Melvin Price Locks and Dam	Sep 1992
Instruction Report GL-87-1	User's Guide: UTEXAS3 Slope-Stability Package; Volume IV, User's Manual	Nov 1992
Technical Report ITL-92-11	The Seismic Design of Waterfront Retaining Structures	Nov 1992
Technical Report ITL-92-12	Computer-Aided, Field-Verified Structural Evaluation	
	Report 1: Development of Computer Modeling Techniques for Miter Lock Gates	Nov 1992
	Report 2: Field Test and Analysis Correlation at John Hollis Bankhead Lock and Dam	Dec 1992
	Report 3: Field Test and Analysis Correlation of a Vertically Framed Miter Gate at Emsworth Lock and Dam	Dec 1993
Instruction Report GL-87-1	User's Guide: UTEXAS3 Slope-Stability Package; Volume III, Example Problems	Dec 1992
Technical Report ITL-93-1	Theoretical Manual for Analysis of Arch Dams	Jul 1993
Technical Report ITL-93-2	Steel Structures for Civil Works, General Considerations for Design and Rehabilitation	Aug 1993
Technical Report ITL-93-3	Soil-Structure Interaction Study of Red River Lock and Dam No. 1 Subjected to Sediment Loading	Sep 1993
Instruction Report ITL-93-3	User's Manual—ADAP, Graphics-Based Dam Analysis Program	Aug 1993
Instruction Report ITL-93-4	Load and Resistance Factor Design for Steel Miter Gates	Oct 1993
Technical Report ITL-94-2	User's Guide for the Incremental Construction, Soil-Structure Interaction Program SOILSTRUCT with Far-Field Boundary Elements	Mar 1994
Instruction Report ITL-94-1	Tutorial Guide: Computer-Aided Structural Modeling (CASM); Version 5.00	Apr 1994
Instruction Report ITL-94-2	User's Guide: Computer-Aided Structural Modeling (CASM); Version 5.00	Apr 1994
Technical Report ITL-94-4	Dynamics of Intake Towers and Other MDOF Structures Under Earthquake Loads: A Computer-Aided Approach	Jul 1994
Technical Report ITL-94-5	Procedure for Static Analysis of Gravity Dams Including Foundation Effects Using the Finite Element Method – Phase 1B	Jul 1994

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Concluded)

	Title	Date
Instruction Report ITL-94-5	User's Guide: Computer Program for Winkler Soil-Structure Interaction Analysis of Sheet-Pile Walls (CWALSSI)	Nov 1994
Instruction Report ITL-94-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Nov 1994
Instruction Report ITL-94-7	User's Guide to CTWALL – A Microcomputer Program for the Analysis of Retaining and Flood Walls	Dec 1994
Contract Report ITL-95-1	Comparison of Barge Impact Experimental and Finite Element Results for the Lower Miter Gate of Lock and Dam 26	Jun 1995
Technical Report ITL-95-5	Soil-Structure Interaction Parameters for Structured/Cemented Silts	Aug 1995
Instruction Report ITL-95-1	User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Criteria (CMITER-LRFD)	Aug 1995
Technical Report ITL-95-8	Constitutive Modeling of Concrete for Massive Concrete Structures, A Simplified Overview	Sep 1995
Instruction Report ITL-96-1	User's Guide: Computer Program for Two-Dimensional Dynamic Analysis of U-Frame or W-Frame Structures (CDWFRM)	Jun 1996
Instruction Report ITL-96-2	Computer-Aided Structural Modeling (CASM), Version 6.00 Report 1: Tutorial Guide Report 2: User's Guide Report 3: Scheme A Report 4: Scheme B Report 5: Scheme C	Jun 1996
Instruction Report ITL-96-3	User's Guide: Computer Program for the Design and Investigation of Horizontally Framed Miter Gates Using the Load and Resistance Factor Criteria (CMITERW-LRFD) Windows Version	Sep 1996

*U.S. GOVERNMENT PRINTING OFFICE: 1996-733-144/40014